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A regionalised review of potential sourcing and sustainability challenges

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Imported wood fuels – a regionalised review of potential sourcing and sustainability challenges.

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Contents

1. Objectives

The University of Copenhagen and the authors of this report were commissioned by the Danish Energy Agency to provide background information for the Danish biomass analysis, which is a result of the political agreement on energy between the Danish government and Venstre, Dansk Folkeparti, Enhedslisten og Det Konservative Folkeparti for 2012 -2020 (Energiaftalen, 22. Marts 2012).

The objective of this analysis was first to provide background knowledge for a general understanding of which wood fuel potentials exist and which are the sustainability challenges to imported wood fuels. To meet this objective, we reviewed relevant recent literature to provide an overview of the following issues:

- Forests of the world
- The global wood fuel trade
- Current and future Danish wood fuel sourcing
- Defining sustainability of wood fuels - selected aspects, including greenhouse gas emission reductions
- International sustainability governance of forest management and biomass and bioenergy

The second objective was to further analyse the wood fuel potentials and sustainability challenges in relation to different current and potential future wood fuel sourcing regions. In meeting this objective, we reviewed relevant statistics and relevant recent literature to provide, region by region, insight into:

- Land use, forest types, and forest ownership
- Public and private international and national regulation for forest and bioenergy sustainability
- Forest resources - wood and wood fuel production and the physical production potentials
- Public and private regulation of forests and nature protection
- Carbon reservoirs and flows in forests and bioenergy production
- Selected sustainability challenges

Starting from the physical existence of a forest biomass resource, there are a number of constraints that limits the final market potential. Two of the most important constraints include the size of a country's or region's forest resources and the sustainability characteristics that these resources possess. These two constraints are the main topics of this report. We point toward the challenges, while it was not possible, within the framework of this report, to quantify the impact of these factors for the market potential. Interested parties may consult the EEA report "How much bioenergy can Europe produce without harming the environment?" to get insight to the considerations surrounding such quantification and what are the potentials in Europe under such constraints (EEA 2006). There are also a number of other factors that determine the final market potential, but which have not been addressed within the framework of this report. These include, for example, the technical and economic constraints for mobilizing the biomass, including the infrastructure in place to produce, harvest, process and transport the biomass. The proximity to Denmark may constrain the potential, even if long distance international transportation of wood fuels from almost all regions of the world is increasingly taking place.

The regions addressed in this report were selected based on knowledge about the size of the forest resources and from impressions of the extent to which the abovementioned constraints occur. Such impressions stem from current sourcing of forest biomass imports to Europe and from the interviews with a handful of biomass buyers in the Danish market. The regions finally selected include:

- Europe (Baltic States, northern, western, eastern, southern Europe, and Russia)
- North America (USA and Canada)
- South America
- Western Africa

Asia, South Africa and Australia also have vast forest biomass resources that may have acceptable sustainability characteristics, but we expect that transport distances so far makes it too costly and complicated to source biomass from these regions.

There are a number of sustainability aspects that are relevant to address, but those that were finally commissioned by the Danish Energy Agency included:

- Reduction of greenhouse gas emissions – ecosystem carbon storages, and in comparison to reference fossil fuels
- Biodiversity
- Soil quality and erosion
- Water quantity and quality, including use of pesticides and nitrogen fertilizer
- Air quality
- Food security

Apart from providing background data and information for overview and understanding of the wood fuel potentials and sustainability challenges in relation to imported wood fuels, the report intends to inform the on-going public debate in Denmark on bioenergy production and use. The history of this debate was recently reviewed by Jorgensen and Andersen (2012).

This report does not intend to unambiguously determine whether particular bioenergy supply chains are sustainable or not. The intention is to present and discuss sustainability issues relating to current and future sourcing of imported forest biomass for energy production in Denmark. The report highlights sustainability issues that should be addressed by the utility sector or policy makers in planning and operating the part of Denmark's energy supply that relies on imported biomass now and in the future.

The main part of the report is written in a technical language intended for an audience with technical insight. A summary intended for policy and decision makers and readers with a more general interest in biomass production, bioenergy and sustainability can be found in the beginning of the report.

2. Summary and conclusions

Biomass is nationally as well as internationally in focus as a renewable energy source, and several countries include biomass in plans for increasing the amount of renewables in the energy mix. Bioenergy is also expected to play a role in the Danish efforts to mitigate climate change, and according to Denmark's National Renewable Energy Action Plan, it is planned to contribute 142 PJ yr^{-1} by 2020. Calculations show that it might be possible to increase the production of biomass in Denmark considerably, maybe up till about 190 PJ yr^{-1} by 2020. However, the import of biomass is increasing and may also play a role in the future.

Forest resources are largest in South America, Russia, North America, Africa (except the northern part), and Asia (except the Western and Central part). In the short-term, the import will most likely come from the Baltic States, Europe, and North America, where resources are substantial, sustainability challenges expected to be small, and where the infrastructure is in place. Russia also has potential, but governance must be examined from case to case, and infrastructures needs improvement. Potential sourcing areas also exist in for example South America and Africa. For example, larger imports from Liberia took place in 2011.

2.1. Forests and forest development

Over the latest millennia more than 50 % of the world's forests have been converted to other land uses to satisfy a growing population's demands for food, materials, heat, housing and infrastructure. That development continues, but at a declining rate at least in the last decade. There are, however, large geographical differences in the forest area dynamics around the world. In Africa and South America the forest area continues to decline, while the development has turned in Europe and North America.

In Africa the forest area is generally decreasing or stable, with harvesting of both industrial wood and wood fuel being stable or increasing. The increasing harvesting is taking place in regions that also experience a decreasing forest area and decreasing carbon stocks, probably reflecting both directly and indirectly caused deforestation and especially forest degradation. The development in carbon stocks is generally following that of the forest area. However, there are deviances from this pattern in southern Africa, and northern and western Europe, where the development in carbon stocks seems to be more positive compared to the development in the forest area.

2.2. Forest management

The regions covered in this report, which have the largest forest resources, also have a relatively high proportion of primary forest, i.e. forest of native species with no indications of forest management activities taking place. In most regions naturally regenerated forests (forests that regenerate naturally but are under some level of forest management) dominate the picture. Particularly in the forests of Northern, Southern and Western Europe, planting or seeding play a large role in forest regeneration, whereas primary forests are practically non-existing. At the global level, in average 36 % of the forested land is classified as primary forest, 57 % as naturally regenerated forest and 7 % as planted or seeded forest.

Much has been achieved during the past decades with regard to defining Sustainable Forest Management (SFM), and the frameworks developed for assessing the sustainable management of forests have shown to be useful. However, an interpretation of SFM criteria and indicators under local conditions is crucial, and the data acquisition for measuring some indicators must be improved. It is also important that systems are adaptive and subjected to continuous improvement based on past experience.

McGinley, Alvarado et al. (2012) conclude: "Ultimately for SFM, it is not the number, rigor, or comprehensiveness of rules and regulations that matter, but the implementation and application of sound practices on the ground. The appropriate mix of laissez faire, discretionary/voluntary guidelines, and nondiscretionary requirements does depend on the country context; the severity of market, social, and/or environmental problems that need to be redressed; the tolerance of the governed for laws; and the ability of governments to implement rules and regulations efficiently and effectively. While fewer rules and requirements may lead to smarter regulation if too many rules and bureaucrats do indeed impede innovation and adaptive management, experience has shown that a lack of rules and/or their implementation can lead to forest degradation and loss. Achieving a balance between these two ends of the spectrum is the continuous challenge for forest stakeholders worldwide."

Sometimes, rare species are associated with managed forest, rather than unmanaged forest. In Denmark, none of the red listed species are found in the unmanaged forests. However, there substantial evidence that unmanaged forests generally support a larger amount of biodiversity than does managed forests, and that a long land use history with intensive use of the forest, often leading to forests being more scattered in the landscape, does results in a lower level of biological diversity (Elbakidze, Angelstam et al. 2011).

2.3. Wood production and global trade

Globally the production of both industrial wood as well as wood fuel has been increasing over the last half century. Wood fuels are increasingly becoming global commodities. The cross border trade of wood fuels has increased more than six folds during the decade from year 2000. However, wood fuel trade is still considerably smaller than the trade with industrial wood. In Denmark, imports of wood pellets have increased over the last decade, while wood chips imports hasn't to the same extent.

Table 1 summarises the development in forest area and forest production in selected regions of the world. Europe generally has increasing or stable forest areas, and wood and wood fuel harvesting. An exception is Eastern Europe, where harvesting decreased after the political changes taking place around 1990.

Table 1. Development in forest area, carbon stocks and wood removals in selected regions from 1990-2010. Based on data in (FAO 2010).

🔴 *Average annual change below -0.5 %.*

🟡 *Average annual change between -0.5% and +0.5 %.*

🟢 *Average annual change above +0.5 %.*

Continent	Region	Forest area		Carbon stock		Wood removals			
						Industrial wood		Fuel wood	
		1990-2000	2000-2010	1990-2000	2000-2010	1990-2000	2000-2005	1990-2000	2000-2005
Africa	East	🔴	🔴	🔴	🔴	🟢	🟢	🟢	🟢
	Central	🟡	🟡	🟡	🟡	🟢	🟡	🟢	🟢
	Northern	🔴	🟡	🔴	🟡	🟢	🟢	🟡	🟢
	Southern	🔴	🔴	🟡	🟡	🟡	🟢	🟡	🟡
	Western	🔴	🔴	🔴	🔴	🟢	🔴	🟢	🟢
America	Northern	🟡	🟡	🟡	🟡	🟡	🟡	🔴	🟡
	South	🟡	🟡	🟡	🟡	🔴	🟢	🔴	🟡
Europe	Eastern	🟡	🟡	🟡	🟡	🔴	🟢	🔴	🟢
	Northern	🟡	🟡	🟢	🟢	🟢	🟢	🟢	🟢
	Southern	🟢	🟢	🟢	🟢	🟡	🟢	🟢	🟢
	Western	🟡	🟡	🟢	🟢	🟢	🟢	🟡	🟢

2.4. Forest disturbance, deforestation, illegal logging

During the 1990's approx. 13 million ha of forest were lost annually due to human intervention or natural causes (e.g. fire, storm, insects). Of these about 4 million ha were primary forest. The corresponding figure was 16 million ha yr^{-1} for the previous decade. The regions most affected by deforestation include South America, Africa, Asia, Eastern Europe, including Russia.

Often it is interactions between the different drivers, rather than single factors, that lead to deforestation. Mining and subsistence agriculture are usually the causes of a relatively limited deforestation for countries in the pre-deforestation phase, whereas commercial agriculture is the dominant cause of large-scale deforestation until the late-transition phase (Hosonuma, Herold et al. 2012). The relative importance of subsistence agriculture does not change much over the different phases, while urban expansion and infrastructure are two major causes of forest clearance in countries that have reached the post-transition phase. Far the largest part of the deforestation takes place in the early-transition phase.

The drivers of forest degradation differ from those of deforestation. Degradation is generally caused by timber and logging activities in countries which are in the pre- and early states of deforestation. In the late-transition phase fuel wood and charcoal production and uncontrolled fires increase in importance, probably because all valuable timber has already been removed (Hosonuma, Herold et al. 2012).

Globalization is seen as a major driving force of deforestation. Lambin and Meyfroidt (2011) identified four underlying mechanisms related to globalization, with the most commonly observed being displacement. Factors leading to displacement include national land zoning policies for nature conservation. Protection of some areas leads to an increased search for cropland and wood products, which may trigger deforestation in other places. Displacement may also work cross borders, for example when developed countries adopt similar protection and conservation policies that lead to their increased import of food and wood products.

Deforestation and forest degradation caused by timber harvesting is often associated with illegal logging. Illegal logging is attributable to poor governance, not only in the countries where illegal logging takes place, but also in countries, where the processing takes place and in consumer countries. In producer countries weak institution with limited resources, poor law enforcement or inadequate forest laws and regulation as well as corruption seems to be major problems leading to illegal logging.

According to Dijk and Savenije (2009), one of the key points in countries' combat of forest degradation and deforestation is to make good forest management a competitive alternative to the illegal activities, while at the same time ensuring that earnings reflect the costs and benefits of the production in a fair manner. Probably one of the most promising tools is REDD+. While Reducing Emissions from Deforestation and Forest Degradation (REDD) is an effort to create a financial value for the carbon stored in forests, the REDD+ additionally includes the role of conservation and sustainable forest management for the enhancement of the forest carbon stocks.

2.5. Bioenergy and climate change

Biomass and bioenergy has in many respect been perceived as CO_2 neutral, but lately the perception has been challenged and debated. The debate partly stems from a weak definition of what CO_2 neutral is and what it requires. Biomass should not, by default, be considered a CO_2 neutral energy resource because a neutrality assumption implies that issues regarding sustainable ecosystem management (managing the long-term productivity, stability and resilience of soil, plants and animals) need not be taken into consideration with reference to bioenergy's potential impact on the climate. However, sustainable management of ecosystems is a key component of the sustainability of bioenergy supply chains and their potential climate benefit.

Probably the most predictive single indicator of anthropogenic climate change is the cumulative GHG emissions to the atmosphere. According to the IPCC's latest assessment report on climate change cumulative CO_2 emissions in the 2012-2100 period should be limited to approx. 990, 2860, or 3890 billion tons respectively to stabilise global warming round 2100 on approx. 1.0, 1.8, or 2.2^{o} C above the temperature average in the 1986-2005 period. The current anthropogenic emission is approx. 38 billion tons CO_2 annually and increasing.

The potential climate benefit of wood as an energy resource alternative to fossil resources is much debated; the temporal dimension probably being the main reason. The temporal dimension relates to the time it takes for a forest ecosystem after harvest to recover all or part of the carbon originally stored in living biomass. This also relates to the difficulties in targeting short term political or production goals with means that work over longer time scales. Forest ecosystems are by nature slowly responding to changing markets, demands and ecological conditions.

Another challenge in evaluating forest bioenergy supply chains is the multi-functionality of a forest production system. Usually biomass for energy is not the main product, but an intermediate product from tending operations or a by-product from the harvest of industrial wood. There is some flexibility for the forest owner or manager to react to market signals by the allocation of wood to different assortments. Industrial grade wood could be used for energy purposes, but the opposite is not always the case. Only a fraction of the fuel wood could realistically be used for industrial purposes, had there not been a demand for energy.

We underline the importance of a transparent analytical framework to evaluate benefits and limitations of using forest biomass to provide energy.

Agostini, Giuntoli et al. (2013) suggest a qualitative evaluation of the climate change mitigation efficiency of different wood assortments (Figure 1). The evaluation is in accordance with the findings presented in this report. However, the evaluation should only be considered as a guideline for different biomass sources relative efficiency. Moreover we find that the short term evaluation (10 years) particularly targets current energy policy goals, while medium and long term evaluations (50 years to centuries) to a larger extent targets climate change mitigation and its physical background.

As discussed in the report such guidelines cannot be used to evaluate the climate change mitigation potential of a specific bioenergy supply chain.

Biomass source	CO_2 emission reduction efficiency					
	Short term (10 years)		Medium term (50 years)		Long term (centuries)	
	coal	natural gas	coal	natural gas	coal	natural gas
Temperate stemwood energy dedicated harvest	---	---	+/-	-	++	+
Boreal stemwood energy dedicated harvest	---	---	-	- -	+	+
Harvest residues*	+/-	+/-	+	+	++	++
Thinning wood*	+/-	+/-	+	+	++	++
Landscape care wood*	+/-	+/-	+	+	++	++
Salvage logging wood*	+/-	+/-	+	+	++	++
New plantation on marginal agricultural land (if not causing iLUC)	+++	+++	+++	+++	+++	+++
Forest substitution with fast growth plantation	-	-	++	+	+++	+++
Indirect wood (industrial residues, waste wood etc)	+++	+++	+++	+++	+++	+++

+/-: the GHG emissions of bioenergy and fossil are comparable; which one is lower depends on specific pathways,

-; --; ---: the bioenergy system emits more CO_2eq than the reference fossil system

+; ++; +++-: the bioenergy system emits less CO_2eq than the reference fossil system

**For residues, thinning & salvage logging it depends on alternative use (roadside combustion) and decay rate*

Figure 1. Efficiency of different biomass resources to reduce anthropogenic CO2 emissions, when displacing different fossil resources. Adopted from (Agostini, Giuntoli et al. 2013).

2.6. Sustainability issues and challenges

Wood fuels are typically made from industrial residues, harvesting residues (after timber harvesting), whole-trees from early thinnings, or low quality wood. As the forests are often managed to produce a range of products, it may be impossible to determine which environmental effects of forest management practices and harvesting operations should be ascribed to each product, even if harvesting of e.g. residues will sometimes mean additional operations, from which additional impacts will arise. All forest management activities may potentially have short-or long-term implications for biodiversity, soil, water etc. The risk is minimised, however, if the forest is managed according to principles for Sustainable Forest Management (adapted to the local context) and principles for adaptive management, and as long as these principles are adequately enforced. For some sustainability issues it is important to consider scale, as impacts of the management may be significant at stand scale or in the short-term, but less significant at the landscape scale or in the long-term.

Wood fuels may also come from dedicated wood energy plantations, possibly using more inputs such as fertilizer, pesticides, irrigation water etc. Such systems will typically be less diverse, and may potentially have larger impacts soil and water, but may also have benefits compared to agriculture, for example in areas where water quality is low due to large nitrate inputs from agricultural fertilization.

One of the potentially most severe environmental impacts of wood energy production will occur if native forests are converted e.g. to intensive energy wood plantations, and similarly, one of the most severe social impacts will be if life-essential agricultural food production is replaced by such systems. It is still uncertain, though, if such conversion is taking place. One of the main courses for forest clearance is still the conversion to food production, e.g. to livestock grazing, to subsistence farming or to commercial crop cultivation, but it cannot be ruled out, that various wood energy production systems will compete for agricultural land in the future.

Sustainability is not an absolute yardstick against which a particular bioenergy supply chain can be measured. It can only be applied as a measure which evaluates the benefits and threats of a certain action against each other, and against alternative actions. When wood fuel production is an integrated part of the forest management, a site specific evaluation is needed to determine if the associated practices must be avoided completely, or if best practices to avoid or mitigate unwanted impacts is enough. Best practices may also be developed for more intensive production systems, similarly to agriculture. Such measures may be enforced by governments, or voluntary certification or it may be part of company practices. As it is difficult to obtain knowledge about long-term impacts of management practices, it is important that management practices are adaptive, i.e. that the efforts made are evaluated continuously to see if they have the desired impact on-the-ground. The management should continuously be adjusted to take account of the monitoring results. The situation around land use changes and competition with food production should also be monitored and followed closely to discover potentially adverse effects and regulate accordingly.

2.7. Governance

FAO (FAO 2010) reports that significant progress has been made during the last decades in developing forest policies, laws and national forest programmes, and that many countries have started or updated these measures since 2000. About 80% of the 233 countries reporting to the Global Forest Resource Assessment give information on their forest governance, and of these about 93% report that they have legislation covering forests, either as a specific national forest law (156 countries), specific subnational laws (6 countries) or under other legislation (17 countries). Countries without forest legislation are usually small island states. Studies also show, that forest legislation in developing countries is often more prescriptive than forest legislation in developed countries. Hence, the challenges no longer relates to the lack of appropriate legislation, but rather to the lack of enforcement.

To ensure legal timber imports to the EU and in support enforcement of legislation, the EU TR was adopted and came into operation in March 2013. It lays down requirements that legality of timber and wood imported to and traded within the EU must be verified using a due diligence system. The EU Timber Regulation (EU TR) was, together with the Voluntary Partnership Agreements, established as a part of the European Union's Forest Law Enforcement (Governance and Trade (FLEGT) Action Plan). These initiatives work together to combat illegal logging and improve forest governance. A number of countries have already concluded agreements with the EU, and are currently developing the systems, which have been agreed upon. Other countries are negotiating an agreement.

Legality is already an integrated part of forest certification schemes, but there are additional requirements in EU TR with regard to the verification systems that are needed (e.g. the due diligence system). The PEFC forest certification system have chosen to implement the requirements of the EU TR into their chain of custody standard, which can now be used for showing compliance with EU TR, while FSC is providing support for showing compliance.

The US Lacey Act has similar aims as the EU FLEGT. It was originally enacted to prohibit transportation of illegal animals including wildlife across U.S. State lines and international borders, but in 2008, the act was extended to include timber, paper and other forest products, with sanctions for anyone in the U.S. who import, export, transport, sell, receive, acquire or purchase illegally-sourced forest products.

The EU TR also applies to energy wood imported to the EU. While the ensuring legality of bioenergy feedstock is crucial to sustainability, it is commonly considered to be not enough. There are a number of other criteria that are also considered as important, including those addressed in this report. A number of initiatives exist, or are under development, to assess sustainability of bioenergy supply chains against a specific set of standards, which expresses the priorities by the standard owners. Such initiatives may take the form of, for example, mandatory regulation (e.g. the EU Renewable Energy Directive) and associated guidelines, or private voluntary certification (ISO, FSC, PEFC, RSB, ISCC etc.). While these initiatives aim at the individual economic operator, the Global Bioenergy Partnership (GBEP) is developing an international framework for national monitoring of bioenergy sustainability, similar to e.g. FOREST EUROPE for Sustainable Forest Management. A larger number of governments and international organizations are behind GBEP, which has a global scope.

It would be ideal that a global initiative set the standards, e.g. within the framework of the U.N. However, experiences show that there only few successful cases of strict international regulation with strong enforcement. In such cases the goal of the regulation is very narrow, or the participation among nations is very low.

National or regional meta-standards, such as the EU Renewable Energy Directive, suffers from problems of legitimacy and democratic shortfalls, e.g. in developing countries. Developing countries may be strongly impacted by such legislation, while they have not taken part in the development of the regulation. It may, however, be the second best option if bioenergy should play a role as a renewable energy form.

While the meta-standard ensures a certain level of ambition, co-regulation, with delegation of compliance responsibilities to e.g. private certification scheme, makes local adaptation possible. While certification costs may be insignificant to larger companies, they may be a significant challenge to small land owners and businesses, especially in developing countries, but also e.g. in south-eastern U.S. While regulation is needed to avoid loss of forest and forest degradation, fewer rules and requirements may sometimes, also in this case, lead to smarter regulation. A way of achieving this balance may be to use national verification methods, which can take account of the existing structures without duplicating them. For example, the Central Point of Expertise on Timber (CPET), a service of the UK Government advising on responsible purchasing, has suggested a framework for verifying sustainability standards on a case to case basis.

Another way forward was attempted by FOREST EUROPE. Signatory countries took the initiative to establish the Intergovernmental Negotiating Committee (INC) for a legally binding agreement on forests in the pan-European region. INC is mandated to develop a legally binding framework agreement for forests that addresses the long-term sustainable forest management in Europe. The idea with this initiative was to adopt comprehensive legislation, and thus avoid adding more layers of governance.

All the efforts need to be evaluated continuously with regard to several aspects, including the comprehensiveness of the standards, the practicability and affordability, and the effectiveness in achieving the standards.

2.8. Regional challenges to sustainability

Ensuring sustainable sourcing of wood for energy broadly requires knowledge, information and insight in many areas, such as GHG emissions, sustainable forest management, biodiversity, human rights, trade and trade regulation, and institutional capacity building. According to (Kittler, Price et al. 2012), importing European bioenergy companies often view the sustainability of their biomass supply as the largest not quantified risk to their business. Whole countries or regions in the world may be excluded due to high likeliness of purchasing unsustainable biomass, but this also means that these countries are deprived of development possibilities and ability to take part in developing global markets. Most likely, it is possible that wood biomass can be sustainably or unsustainably sourced from all regions in the world, but ensuring sustainability of a particular supply chain involving the more risk prone regions probably requires meticulous collection of information about where and how biomass is harvested, and in what economic and societal framework harvest takes place. It may also need cooperation with local organisations and/or authorities, and perhaps even local presence. Certification schemes may be helpful in this sense, but are not always an option.

Table 2 below summarizes some major opportunities and challenges that exist in relation to sustainable biomass sourcing in the regions treated in this report. Even in the most advanced forestry countries, with no significant conversion, comprehensive monitoring systems, good legal frameworks, several good practice and even sometimes biomass harvesting guidelines, it remains a challenge to continuously investigate and monitor effects of different practices on site fertility, carbon stores, biodiversity and water, in order to build up more knowledge on how this develops depending on site conditions and site history, and stand properties.

Table 2. Summary of sustainability issues and challenges in the regions covered in the report.

Region	Opportunities	Challenges
North Europe	Forest area increasing High degree of 3. party certification Good legal framework Biomass harvesting guidelines exist and are in use	High exploitation rate Continued research and monitoring of impacts
Baltic States	Forest area increasing Good legal framework	Medium degree of 3. party certification Research and monitoring of impacts
West Europe	Forest area increasing Medium to high degree of 3. party certification Good legal framework	Increasing exploitation rate Medium to high degree of 3. party certification Research and monitoring of impacts
East Europe	Good legal framework	Low to high degree of 3. party certification Some degree of corruption Research and monitoring of impacts
South Europe	Mostly low degree of exploitation	Mostly low degree of 3. party certification Research and monitoring of impacts

Russia	Large resource base Low exploitation rate Good legal framework Clear ownership	Very low degree of 3. party certification Illegal logging or re-export of illegal timber Corruption Research and monitoring of impacts
Canada	Large resource base High degree of 3. party certification Good legal framework and enforcement	Clashing primary forest definitions Slightly decreasing forest area Continued research and monitoring of impacts
USA	Large resource base Forest area increasing Good legal framework Good water protection framework Biomass harvesting guidelines exist in several states	Low to medium degree of 3. party certification Ownership structure in relation to implementation of verification systems Water protection Biodiversity protection particularly in SE Research and monitoring of impacts
South America	Large resource base Improved governance and law enforcement	Declining forest area, with implications for several environmental issues Illegal logging Very low degree of 3. party certification Corruption and law enforcement Unclear tenure rights Research and monitoring of impacts
West Africa	Large production potentials	Not well known resource base Declining forest area, with implications for several environmental issues Mostly very low degree of 3. party certification Large population and income growth Increased local demand for biomass Illegal logging Corruption and law enforcement Weak institutions and governance Unclear tenure rights Research and monitoring of impacts

3. Sammendrag og konklusioner

Biomasse er såvel nationalt som internationalt i fokus som en vedvarende energikilde, og flere lande inkluderer biomasse i deres nationale energiplaner for at øge anvendelsen af vedvarende energi. Bioenergi forventes også at spille en rolle i den danske klimaindsats. Ifølge Danmark Nationale Handlingsplan for vedvarende energi er det planen at biomasse skal bidrage 142 PJ yr^{-1} i 2020. Beregninger viser, at man muligvis kan øge produktionen af biomasse i Danmark betragteligt, måske op til omkring 190 PJ yr^{-1} i 2020. Imidlertid er importen af biomasse stigende og importeret biomasse kan også komme til at spille en rolle i fremtiden.

De største skovressourcer findes i Sydamerika, Rusland, Nordamerika, Afrika (undtagen den nordlige del) og Asien (undtagen det vestlige og centrale del). På kort sigt vil importen sandsynligvis komme fra de baltiske lande, Europa og Nordamerika, hvor ressourcerne er betydelige, udfordringerne i forhold til bæredygtighed forventes at være forholdsvis små, og infrastrukturen er på plads. Rusland har også et stort eksportpotentiale, men bæredygtighedsspørgsmålet må undersøges fra sag til sag, og infrastrukturerne er ikke optimale. Potentielle eksportområder findes også i Sydamerika og Afrika. For eksempel fandt større import fra Liberia sted i 2011.

3.1. Skovene og deres udvikling

Over de seneste årtusinder er mere end 50 % af verdens skove blevet konverteret til andre arealanvendelser for at tilfredsstille en voksende befolknings behov for føde, materialer, varme, byområder og infrastruktur. Denne udvikling fortsætter, dog med aftagende hastighed i det sidste årti. Der er dog store geografiske forskelle i forhold til skovarealets dynamik rundt om i verden. I Afrika og Sydamerika fortsætter skovarealet med at falde, mens udviklingen er vendt i Europa og Nordamerika. I Afrika er skovarealet generelt faldende eller stabil, og hugsten af både industritræ og træbrændsel er stabil eller stigende. Den stigende hugst finder sted i regioner, der også oplever et faldende skovareal og faldende kulstoflagre, hvilket formentlig afspejler en skovrydning forårsaget af både direkte og indirekte årsager, mens overudnyttelse og skovdegradering ofte er en direkte følge af hugsten. Udviklingen i skovens kulstoflager følger generelt udviklingen i skovarealet. Der er dog afvigelser fra dette mønster i det sydlige Afrika og Nord-og Vesteuropa, hvor kulstoflagrene synes at udvikle sig i mere positiv retning end skovarealet.

3.2. Skovdrift

De regioner, der er omfattet af denne rapport, og som har de største skovressourcer, har også en relativ høj andel af primær skov, dvs. skov af hjemmehørende arter uden tegn på menneskelige aktiviteter i skoven. I de fleste regioner dominerer naturligt foryngede skove billedet (dvs. skove, der forynges naturligt, men er under et vist niveau af skovdrift). Det gælder især skovene i det nordlige, sydlige og vestlige Europa, hvor plantning eller såning også spiller en stor rolle, mens primær skove er praktisk taget ikke-eksisterende . På globalt plan gennemsnitligt 36 % af skovarealet klassificeret som primær skov, 57% som naturligt forynget skov og 7% som plantet eller sået skov.

Meget er opnået i løbet af de seneste årtier med hensyn til at definere bæredygtig skovdrift, og de kriterier og indikatorer, som er udviklet til vurdering af bæredygtig skovdrift har vist sig at være nyttige. Men det er afgørende, at kriterier og indikatorer tilpasses til lokale forhold, og at dataindsamlingen til måling nogle indikatorer forbedres. Det er også vigtigt, at dyrkningssystemerne er 'adaptive', hvilket vil sige at de løbende forbedres, baseret på monitering og tidligere erfaringer.

McGinley, Alvarado et al. (2012) konkluderer: "I sidste ende er det ikke antal, stringens, eller fuldstændighed, der er afgørende i forhold til regler og bestemmelser, men gennemførelsen og anvendelsen af god praksis i forvaltningen af økosystemerne. Den optimal blanding af laissez-faire, diskretionære/frivillige retningslinjer og ikke-diskretionære krav er afhængig af den nationale sammenhæng de indgår i; hvor vanskeligt markedet er, de sociale og/eller miljømæssige problemer, der skal afhjælpes; folks tolerance overfor lovgivning; og regeringernes evne til at gennemføre regler og forordninger effektivt. Mens færre regler og krav kan føre til mere intelligent regulering, end hvis alt for mange regler og bureaukrater faktisk hindrer innovation og adaptiv forvaltning, har erfaringerne vist, at mangel på regler og/eller deres gennemførelse kan føre til overudnyttelse og afskovning. Det at opnå en balance mellem disse to ender af spektret er den konstante udfordring for skovinteressenter over hele verden".

Nogle gange er sjældne arter forbundet med skov under skovdrift, snarere end urørt skov. I Danmark findes ingen af de rødlistede arter i urørte skove. Men der betydelige beviser for, at urørte skove generelt understøtter en større biodiversitet end de forvaltede skove, og at en arealanvendelse historie med lang tids intensiv brug af skoven, hvilket ofte fører til mere spredte skove, r resulterer i en lavere grad af biodiversitet (Elbakidze , Angelstam et al. 2011).

3.3. Træprodukter og global handel

Globalt har produktion af både industrielt træ og træbrændsel været stigende i det sidste halve århundrede. Handlen med træbrændsler er i stigende grad global. Den internationale handel med træbrændsler er steget med mere end en faktor seks fra 2000 til 2010. Men handlen med træbrændsel er stadig betydeligt mindre end handlen med industrielt træ. I Danmark er importen af træpiller steget i det seneste årti, mens importen af træflis import ikke er fulgt med.

Tabel 1 opsummerer udviklingen i skovareal og produktion i udvalgte regioner i verden. Europa har generelt stigende eller stabile skovarealer, samt en stabil hugst af træ og brændsel. En undtagelse er Østeuropa, hvor hugsten faldt efter de politiske forandringer, der fandt sted omkring 1990.

3.4. Skovforstyrrelser, skovrydning og illegal hugst

I løbet af 1990'erne er ca. 13 millioner ha skov gået tabt årligt på grund af menneskelige indgreb eller af naturlige årsager (f.eks. brand, storm, insektskader). Af disse var omkring 4 millioner ha primær skov. I det foregående årti var dette tal 16 millioner ha årligt. De regioner, som er hårdest ramt af afskovningen, omfatter Sydamerika, Afrika, Asien, Østeuropa, herunder Rusland.

Ofte er det samspillet mellem forskellige faktorer, snarere end den enkelte, der fører til skovrydning. Minedrift og subsitenslandbrug er normalt årsagerne til en relativt begrænset skovrydning i lande som er i en før-skovrydningsfase, hvorimod det kommercielle landbrug er den dominerende årsag til en omfattende skovrydning i lande som er i en tidlige til sen overgangsfase (Hosonuma , Herold et al. 2012). Den relative betydning af subsistenslandbrug ændrer sig ikke meget i løbet af de forskellige skovrydningsfaser, mens byernes ekspansion og opbygning af infrastruktur er to vigtige årsager til skovrydning i lande, der har nået den efter overgangsperioden. Langt den største del af skovrydningen foregår i den tidlige overgangsperiode.

De faktorer som leder til overudnyttelse afviger fra de faktorer der leder til afskovning. Overudnyttelse er normalt forårsaget af tømmerhugsten i lande, der er i før-skovrydning og tidlig overgangsfase. I sen-overgangsfasen bliver brænde og trækulsproduktion, og ukontrollerede brande af øget betydning, sandsynligvis fordi alt værdifuldt tømmer allerede er blevet fjernet (Hosonuma , Herold et al. 2012).

Globaliseringen ses også som en væsentlig faktor i forbindelse med skovrydning. Lambin og Meyfroidt (2011) identificerede fire underliggende mekanismer relateret til globalisering, med såkaldt 'fordrivelse' som den mest almindeligt forekommende. Faktorer, der fører til fordrivelse kan omfatte nationale politikker for naturbeskyttelse. Beskyttelse af visse områder fører til en øget søgning efter dyrkningsarealer, der kan udløse skovrydning andre steder. 'Fordrivelse' kan være international, for eksempel hvis industrialiserede lande vedtager tilsvarende naturbeskyttelsespolitikker, der fører til deres øgede import af fødevarer og træprodukter.

Skovrydning og overudnyttelse forårsaget af tømmerhugst er ofte forbundet med ulovlige skovning. Ulovlig skovning skyldes især dårlig effektuering af lovgivning, ikke kun i de lande, hvor ulovlig skovhugst finder sted, men også i lande hvor træet bearbejdes og i lande hvor træprodukterne sælges. Svage institutioner, med begrænsede ressourcer, dårlig retshåndhævelse, utilstrækkelige skovlove og regler, samt korruption kan være problemer, der fører til ulovlig skovhugst i de træproducerende lande.

Ifølge Dijk og Savenije (2009) er en af de centrale punkter i landenes bekæmpelse af overudnyttelse og skovrydning at gøre en god skovforvaltning til et konkurrencedygtigt alternativ til de ulovlige aktiviteter, mens det samtidig sikres, at indtjeningen afspejler produktionens omkostninger og fordele på en retfærdig måde. Et af de mest lovende værktøjer er sandsynligvis REDD+. Mens reduktion af emissioner fra skovrydning og skovødelæggelse (REDD) er et forsøg på at give skovens kulstoflager en økonomisk værdi, kan man under REDD+ derudover indregne virkningen af en bæredygtig skovforvaltning, som øger skovens kulstoflagre.

3.5. Bioenergi og klimaændringer

Biomasse og bioenergi er i mange henseender blevet opfattet som CO_2-neutral, men på det seneste er denne opfattelse blevet udfordret og debatteret. Debatten skyldes dels en uklar definition af, hvad CO_2-neutral betyder og kræver. Biomasse bør ikke som udgangspunkt betragtes som en CO_2 neutral energiressource, da en sådan antagelse indebærer, at spørgsmål vedrørende bæredygtig forvaltning af økosystemer ikke behøver at tages i betragtning i forhold til bioenergiens potentielle indvirkning på klimaet. Men bæredygtig forvaltning af økosystemer er helt central for bioenergiens bæredygtighed og dens potentielle klimafordele.

Den formentlig bedste indikator for menneskeskabte klimaændringer er de kumulerede drivhusgasemissioner til atmosfæren. Ifølge den seneste evalueringsrapport fra IPCC om klimaændringer bør de samlede CO_2-emissioner i perioden 2012-2100 begrænses til hhv. ca. 990, 2860, eller 3890 milliarder tons for at sikre at den globale opvarmning i år 2100 begrænses til hhv. ca. 1,0, 1,8 eller 2,2^{o} C i forhold til gennemsnittemperaturen i 1986-2005. Den nuværende menneskeskabte emission er på ca. 38 mia. tons CO_2 årligt og det tal er stigende.

Den potentielle klimafordel af at bruge træ til energi, som et alternativ til fossile ressourcer, er meget omdiskuteret, og den tidsmæssige dimension er formentlig den vigtigste årsag til denne diskussion. Den tidsmæssige dimension vedrører den tid, det tager for et skovøkosystem efter hugst at genindvinde hele eller dele af det oprindeligt lagrede kulstof i den levende biomasse. Dette illustrerer også hvor vanskeligt det er at adressere kortsigtede politiske eller produktionsmæssige mål med mere langsigtede virkemidler. Skovøkosystemer reagerer af natur langsomt på skiftende markeder, efterspørgsel og økologiske forhold.

En anden udfordring ved evalueringen af skovbaseret bioenergi er den multifunktionalitet, der er indbygget i et skovproduktionssystem. Normalt er energitræet er ikke det vigtigste produkt fra skoven, men et biprodukt af bevoksningspleje, eller et biprodukt fra hugsten af industrielt træ. Der er en vis fleksibilitet til at reagere på markedssignaler ved at ændre på fordelingen at hugsten til forskellige træsortimenter. Industrielt træ kan godt bruges til energiformål, men det modsatte er ikke nødvendigvis tilfældet. Kun en del af brændselstræet kunne realistisk set bruges til industrielle formål, hvis der ikke havde været en efterspørgsel på energitræ.

Agostini , Giuntoli et al. (2013) forslår, en kvalitativ vurdering af forskellige træsortimenters klimamæssige effektivitet (Figur 1). Evalueringen er i overensstemmelse med de resultater, der fremlægges i denne rapport. Imidlertid bør evalueringen kun betragtes som en retningslinje for forskellige biomasseressourcers relative effektivitet. Desuden finder vi, at en kortsigtet evaluering (10 år) især er relevant i forhold til aktuelle energipolitiske mål, mens evalueringer på mellem og langt sigt (50 år til århundreder) i højere grad retter sig mod de langsigtede klimaændringer og mulighederne for at begrænse dem.

3.6. Bæredygtighedsudfordringer

Træbrændsler er typisk fremstillet af industrielt affald (samsmuld og spåner), hugstaffald, tyndingstræ eller træ af lav kvalitet. Da skovene ofte producerer en række andre produkter ud over energitræ, kan det være umuligt at afgøre, hvilke miljømæssige effekter der skal tilskrives det enkelte produkt. Alle skovdriftsaktiviteter kan potentielt have både kort- eller langsigtede konsekvenser for biodiversitet, jordbund, vand m.m. Risikoen kan reduceres hvis skoven drives efter principper for bæredygtig skovforvaltning og principper for adaptiv styring.

Træbrændsler kan også komme fra dedikerede energiplantager, eventuelt med input af en række hjælpestoffer som gødning, pesticider, kunstvanding m.m. Sådanne dyrkningssystemer vil typisk være mindre diverse, og kan potentielt have større konsekvenser for jord og vand, men de kan også have fordele i forhold til landbrug, for eksempel i områder, hvor vandkvaliteten er lav på grund af nitratudvaskning.

En af de potentielt mest alvorlige miljøpåvirkninger fra bioenergiproduktion vil forekomme, hvis oprindelige skove konverteres til f.eks. intensive energiplantager. På samme måde kan konvertering af subsistenslandbrug til energiproduktion have alvorlige sociale konsekvenser. En af de væsentligste årsager til skovrydning er stadig konvertering til fødevareproduktion, f.eks. til græsning, subsistenslandbrug eller kommerciel produktion.

Bæredygtighed kan ikke anvendes som en absolut målestok til at evaluere specifikke bioenergi forsyningskæder. Begrebet kan kun anvendes til at vurdere fordele og ulemper ved specifikke tiltag mod hinanden og mod alternative tiltag. Foranstaltninger og rutiner, der kan sikre bæredygtighed af skovproduktion kan håndhæves gennem lovgivning, via frivillig certificering, eller det kan være en del af en virksomheds praksis.

3.7. Forvaltning

FAO (2010) rapporterer, at der er gjort betydelige fremskridt i de seneste årtier i udviklingen af skovpolitikker, love og nationale skovprogrammer, og at mange lande har begyndt eller ajourført sådanne foranstaltninger siden 2000. Omkring 80 % af de 233 lande, der indberetter til FAO's Global Forest Resource Assessment bidrager med oplysninger om deres skovforvaltning, og 90 % af disse at de har en lovgivning, der dækker skovene, enten som en specifik national skovlov (156 lande), særlige subnationale love (6 lande), eller efter anden lovgivning (17 lande). Lande uden skovlovgivning er som regel små østater.

Undersøgelser viser, at skovlovgivning i udviklingslandene ofte er mere normgivende end skovlovgivning i udviklede lande. Derfor er udfordringen ikke længere mangel på passende lovgivning, men snarere manglende håndhævelse.

For at sikre import af lovligt træ til EU og for at støtte håndhævelsen af lokal lovgivning, trådte EU's tømmerregulativ (EU TR) i kraft i marts 2013. Det fastlægger krav om at lovligheden af træ, der importeres til og handles inden for EU, skal kontrolleres ved hjælp af uafhængige instanser. EU TR blev etableret sammen med frivillige partnerskabsaftaler som en del af EU's praksis for god forvaltning og handel (FLEGT). Med disse initiativer samarbejdes der om at bekæmpe ulovlig skovhugst og forbedre skovforvaltning. En række lande har allerede indgået aftaler med EU, og er ved at udvikle de kontrolsystemer, som er blevet aftalt. Andre lande er stadig i forhandlingsfasen.

Lovligheden er allerede en integreret del af skovcertificeringsordninger, men der er yderligere krav i EU TR med hensyn til de kontrolforanstaltninger, der er nødvendige. PEFC skovcertificeringsordning har valgt at implementere kravene i EU TR i deres chain-of-custody standard, som nu kan bruges til at sikre overholdelse af EU TR. FSC yder støtte til sikring af overholdelse af EU TR.

Den amerikanske Lacey Act har lignende målsætninger som FLEGT. Det blev oprindeligt vedtaget, at forbyde transport af ulovlige dyr, herunder vilde dyr mellem stater i USA og på tværs af internationale grænser, men i 2008 blev loven udvidet til at omfatte træ, papir og andre skovprodukter med sanktioner for alle i USA, der importer, eksporter, transporterer, sælger, modtager, erhverver eller køber ulovligt høstede skovprodukter.

EU TR gælder også for energitræ, der importeres til EU. Mens det at sikre lovligheden af biomasse til energi er afgørende for bæredygtigheden, er det dog ikke nok til at sikre bæredygtighed. Der er en række andre kriterier, som også er vigtige, herunder dem, der behandles i denne rapport. En lang række initiativer er allerede iværksat, eller er under udvikling, for at vurdere bæredygtigheden af bioenergi forsyningskæder. Disse initiativer er enten obligatorisk regulering (f.eks. EU direktivet om vedvarende energi) og tilknyttede retningslinjer eller frivillig certificering (ISO, FSC, PEFC, RSB, ISCC osv.). Mens disse initiativer sigter på den enkelte erhvervsdrivende, er Global Bioenergy Partnership (GBEP) i gang med udvikling af en internationalt anerkendt ramme for national overvågning af bæredygtigheden af bioenergiproduktion og anvendelse.

Initiativet svarer til fx FOREST EUROPE for bæredygtig skovforvaltning. Et større antal regeringer og internationale organisationer står bag GBEP, som er udviklet i regi af FAO.

Det ville være ideelt, at standarder sættes f.eks. inden for rammerne af FN. Imidlertid er der kun få vellykkede tilfælde af international regulering med effektiv håndhævelse, der omfatter alle relevante lande og regioner.

Nationale eller regionale meta-standarder, som EU's direktiv for vedvarende energi, kan være problematiske i relation til legitimitet og demokratiske indhold for f.eks. udviklingslande. Udviklingslandene kan blive stærkt påvirket af en sådan lovgivning, men de har ikke deltaget i udviklingen af lovgivningen.

Mens meta-standarder sikrer et vist ambitionsniveau kan uddelegering af ansvar til private certificeringsordning sikre lokal tilpasning og accept. Certificeringsomkostninger kan være betydelig for større virksomheder, men kan ses som uoverstigelige udfordringer for små jordejere og virksomheder, især i udviklingslande, men f.eks. også i det sydøstlige USA. Hvor regulering er nødvendig for at undgå tab af skov og skovødelæggelse, kan færre regler og krav undertiden føre til smartere regulering, der også kan overkommes af mindre skovejere og virksomheder. En måde at sikre denne balance kan være at benytte nationale verifikationsmetoder, som kan tage højde for de eksisterende strukturer uden at overlappe dem. Et eksempel er Central Point of Expertise on Timber (CPET), en service, der udbydes af den britiske regering med rådgivning om ansvarligt indkøb.

En anden løsning er forsøgt af FOREST EUROPE. Deltagende lande tog initiativ til at etablere Den Mellemstatslige Forhandlingskomité (INC). INC har mandat til at udvikle en juridisk bindende rammeaftale for skove, der behandler den langsigtede bæredygtige skovforvaltning i Europa. Ideen med dette initiativ var at vedtage passende lovgivning, og dermed undgå flere lag af regulering.

Alle bestræbelser bør evalueres løbende med hensyn til fuldstændighed af standarderne, den praktiske implementering, omkostninger, og effektiviteten i gennemførelsen af standarderne.

3.8. Regionale bæredygtighedsudfordringer

Sikring af bæredygtig import af træ til energi kræver viden, information og indsigt på mange områder, såsom drivhusgasemissioner, bæredygtig skovforvaltning, biodiversitet, menneskerettigheder, handel og regulering. Ifølge (Kittler, Price et al. 2012) betragter mange europæiske virksomheder, der importerer biomasse til energi bæredygtigheden af deres biomasseforsyninger som den største ikke kvantificerede risiko for deres virksomhed. Hele lande eller regioner kan udelukkes på grund af stor sandsynlighed for at købe ikke-bæredygtig biomasse, men det betyder også, at disse lande bliver frataget udviklingsmuligheder for at deltage på globale markeder. Det er sandsynligvis muligt importere såvel bæredygtig som ikke-bæredygtig træbiomasse fra alle regioner i verden, men at sikre bæredygtigheden af en bestemt forsyningskæde, der involverer lande eller regioner med høj risiko for at biomasseproduktion ikke er bæredygtig kræver omhyggelig indsamling af oplysninger om, hvor og hvordan biomassen er høstet, og i hvilke økonomiske og samfundsmæssige rammer høst og forarbejdning finder sted. Der kræves formentlig også samarbejde med lokale organisationer og/eller myndigheder, og måske endda lokal tilstedeværelse. Anerkendte certificeringsordninger kan være nyttige i denne henseende, men er ingen garanti og heller ikke altid en mulighed.

Tabel 2 opsummerer muligheder og udfordringer i relation til bæredygtig biomasse import i de regioner, der behandles i denne rapport. Selv i lande med veludviklet skovbrugspraksis, uden omfattende konvertering af skov, med omfattende overvågningssystemer, gode juridiske rammer m.m. er det stadig en udfordring løbende at undersøge og overvåge virkningerne af forskellige praksis på jordbudsforhold, kulstoflagre, biodiversitet og vand, med henblik på at opbygge mere viden om, hvordan dette udvikler sig.

4. Introduction

Biomass is nationally as well as internationally in focus as a renewable energy source. The current (2008) modern[1] use of bioenergy is of about 11 EJ yr^{-1} and total bioenergy use, including firewood for subsistence in developing countries, of about 50 EJ yr^{-1} (Chum, Faaij et al. 2011). Based on expert reviews conducted for the compilation of the IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN) potential deployment levels of biomass for energy could be between 100 and 300 EJ by 2050, with the large uncertainties associated with projections that depend on the development of policies, markets, technologies and food production taken into consideration ((Chum, Faaij et al. 2011), page 214).

In a review of 137 scenario analyses IPCC report that biomass could contribute about 150 EJ yr^{-1} by 2050 to keep the CO_2 concentration in the atmosphere below 440 ppm ((Fischedick, Schaeffer et al. 2011), page 809). Most scenarios (135) are based on a study by (Krey and Clarke 2011). The current annual global production of wood corresponds to ~26 EJ yr^{-1} with ~12 EJ yr^{-1} in the form of industrial round wood and ~14 EJ yr^{-1} as wood fuel (Heinimö and Junginger 2009, FAO 2012). In this perspective a very large increase in the use of biomass for energy purposes is projected to meet the targets as set by e.g. the United Nations Framework Convention on Climate Change (UNFCCC)

Bioenergy is also expected to play a role in the Danish efforts to combat climate change. Denmark's gross final energy consumption was, in 2011, 807 PJ (Energistyrelsen 2012) with an EU set target for the overall share of energy from renewable sources in gross final energy consumption of 30 % by 2020 (European Parliament and the Council 2009). The long term vision is 100 % renewable energy consumption, including the transport sector by 2050 (Regeringen 2011). The share of renewables in the Danish energy consumption was 17 % in 2005, increasing to 23.6 % by 2011 corresponding to 135 PJ yr^{-1}, of which 83 PJ stem from bioenergy (Energistyrelsen 2012).

Specific targets for the use of biomass in Danish energy production was first set in the 1993 (Regeringen 1993), with later modifications in 1997 and 2000 stipulating the use of 1.4 million tons biomass by 2000. The initially mandated allocation was 1.2 million tons of straw and 0.2 million tons wood chips. In the subsequent modifications the mandated allocation was to some extent released, but the target remained, and was reached around 2008. According to Denmark's National Renewable Energy Action Plan (NREAP) Denmark is expected to use 142 PJ of biomass-based energy (including waste) by 2020 (Klima og Energiministeriet 2010), corresponding to 17% of the current energy consumption. Calculations show that it might be possible to increase the production of biomass in Denmark by 10 million tons of dry matter or about 190 PJ yr^{-1} by 2020 (including straw and other agricultural residues, and assuming energy contents of

[1] The term 'modern' refers to conversion of biomass to energy services in technologically advanced installations such as power plants, district heating systems, combined heat and power production, pyrolysis or gasification to liquid or gaseous fuels. These technologies are, from a thermodynamic point of view, more efficient than 'traditional biomass use' to convert chemically stored energy in biomass to energy services. Traditional biomass use includes the use of biomass for heating, cooking, provision of light and protection without use of advanced technologies, e.g. on the ground or in stoves.

19 MJ kg^{-1}) (Gylling, Jørgensen et al. 2012). However, it is still expected that imported biomass will play a significant role.

Several countries are transforming their energy systems to use of renewable resources, and many of them, similarly to Denmark, look into the possibilities that domestic and imported biomass offer. At the same time, it is expected that the global demand for food, energy, raw materials and chemicals will increase as the global population and its per capita consumption increases (Smith, Haberl et al. 2013). The increased demand for biomass could lead to increased global prices that could be determining for the use of biomass resources in energy supplies. The increased demand will also lead to an increased pressure on biomass resources and there are examples that this has already led to severe unintended effects for nature and environment, for example deforestation in Asia to create large scale oil palm plantations.

To avoid such unintended effects, the EU RES Directive from 2009 set sustainability criteria for production and use of biomass for energy. So far, the criteria are only mandatory for transportation biofuels and bioliquids (European Parliament and the Council 2009), but the European Commission later recommend that Member States voluntarily use the same criteria for solid and gaseous biomass used in the production of heat, electricity and cooling (European Commission 2010). Some countries in Europe have introduced national sustainability criteria for solid and gaseous biomass fuels used for heat, electricity and cooling. Germany established a system already before 2009, which was later changed to comply with EU RES criteria. Belgium and the United Kingdom have also implemented sustainability criteria, while the Netherlands have developed a voluntary system (Pelkmans, Goovaerts et al. 2013). The Commission is currently reviewing the national progress and effects on the market to see if common mandatory sustainability criteria are needed, also for solids and gaseous biomass for electricity, heat and cooling, and various workshops and meetings have been arranged since 2011 to give scientific inputs to the process. A series of workshops were for example arranged by JRC and IINAS, recommending to focus on criteria for GHG emission reductions, biodiversity, and sustainable forest management (Fritsche, Iriarte et al. 2012). The Commission’s recommendations were first expected as early as end of 2011, but are currently expected in the autumn 2013 or maybe in 2014.

Concerns around climate mitigation benefits of using food-biomass for energy has lately led the European Commission to suggest an additional requirement concerning the use of biofuels in the transportation sector; that the use of food-based biofuels to meet the 10 % renewable energy target by 2020 should be limited to 5 %, and impacts of indirect land-use change (iLUC) should be included as standard emissions factors for cereals, sugars and oil crops (European Commission 2012, Pelkmans, Goovaerts et al. 2013). It is currently uncertain whether such requirements will also be set for solid and gaseous biomass for heat, power and cooling.

Danish energy policies aim at exploring the possibilities to increase the use of biomass for energy in a sustainable manner and as a part of the Danish energy agreement from spring 2012, an analysis should be performed on the use of biomass for energy in Denmark. This report is part of that analysis. The biomass analysis will include issues as international biomass potentials and the sustainability of different types of biomass production systems and uses. As regards sustainability, the main focus is on the emission of greenhouse gases, although other sustainability aspects should also be addressed.

5. Basic concepts

5.1. Defining wood fuels

For the purpose of this report we define wood fuels as 'all types of biofuels originating directly or indirectly from woody biomass', with biofuels meaning 'fuel produced directly or indirectly from biomass' (FAO 2004). In an EU context, 'biofuels' mean transportation fuels, and therefore we will specify the type of biofuel by its end-use throughout the report (i.e. biofuels for transportation, or biofuels for heat, power and cooling).

5.2. Land use categories producing wood fuels

Wood fuels may origin from forest, other wooded land or plantations, where trees are grown in shorter or longer rotations, for example in short rotation coppice systems (SRC) or short rotation forestry systems (SRF). Typical tree species used for plantations and coppice systems in Europe are willow (*Salix spp*), poplar (*Populus spp*) and eucalypt (*Eucalytus spp*) (Nordh and Dimitriou 2003). Eucalypt and pine species (*Pinus spp*) are also a common fast growing species grown in plantations in southern Europe and other parts of the world, for example in South America (Faúndez 2003), and South-eastern USA (Kittler, Price et al. 2012). Wood fuels may also origin from trees outside forest, including for example nature reserves, hedgerows and windbreaks, arboriculture and urban parks. Trees outside forest may contribute significantly to industrial wood fuel supplies in developed countries (Prinz, L. et al. 2008). Only wood from forests, dedicated energy crops and residues from wood industries will be considered in this report. Due to lack of reliable data, other resources are not considered.

FAO define forest as: Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 %, or trees able to reach these thresholds *in situ* (FAO Forestry Department 2010). There are several national forest definitions, but the definition of FAO is increasingly being used in national forest inventories. The definition of 'other wooded land' is: Land not classified as forest, spanning more than 0.5 hectares; with trees higher than 5 meters and a canopy cover of 5-10 %, or trees able to reach these thresholds *in situ*; or with a combined cover of shrubs, bushes and trees above 10 % (FAO Forestry Department 2010). Plantations are included in the FAO definition of forest, but they still have certain characteristics that distinguish them from natural forest. They are defined as: Forests predominantly composed of trees established through planting and/or deliberate seeding. The planted/seeded trees are expected to constitute more than 50 % of the growing stock at maturity. According to this definition, plantations or planted forests includes coppice from trees that were originally planted or seeded (FAO Forestry Department 2010).

Different sustainability concerns may dominate depending on the feedstock production system. A high level of sustainability concerns surrounds native, unmanaged forest and forest that entirely serve for protection purposes. Concerns are also substantial for forests managed for a multiple of economic, environmental and social services or values, where focus is on protection of especially environmental and social services and values that are not monetized. For forests approaching the characteristics of a plantation, with the management in some regards resembling agricultural management, for which sustainability approaches are more often described by concepts as 'integrated production' or 'best practices' for a given crop, with the overall principle being to use as few inputs as possible, but still as many as needed for that particular crop.

Sustainability issues that are important in relation to land management and the primary production of the wood are independent of the end-use, and for multifunctional forests it is not possible to separate the sustainable production of wood for energy from sustainable production of wood or non-wood products grown for other purposes. With the number of years involved from planting until harvesting, the markets also often change and the wood produced may be sold for other purposes than intended at the time of the planting.

In some parts of the world, for example Australia and New Zealand, all wood production takes place in plantations as native forests are protected from harvesting (Mark Brown, University of Sunshine Coast, Australia, pers. comm.). Also in other countries, wood from plantations constitute a considerable part of the supplies (Figure 2), with the amount of planation area increasing in some parts of the world, and decreasing in other parts (Figure 3).

In other parts of the world, the emphasis is on multifunctional forestry, with integration between protection/conservation and the productive functions of forests. This is for example a bearing principle in management of European forests, with forest producing of wood, but also providing several environmental services, such as biodiversity, water quality and recreation (FOREST EUROPE, UNECE et al. 2011).

Figure 2. Ten countries with the largest percentage of productive forest plantation (GRID-Arendal 2013), http://www.grida.no/graphicslib/detail/ten-countries-with-the-largest-area-of-productive-forest-plantations_d154. Credited Philippe Rekacewicz assisted by Cecile Marin, Agnes Stienne, Guilio Frigieri, Riccardo Pravettoni, Laura Margueritte and Marion Lecoquierre.

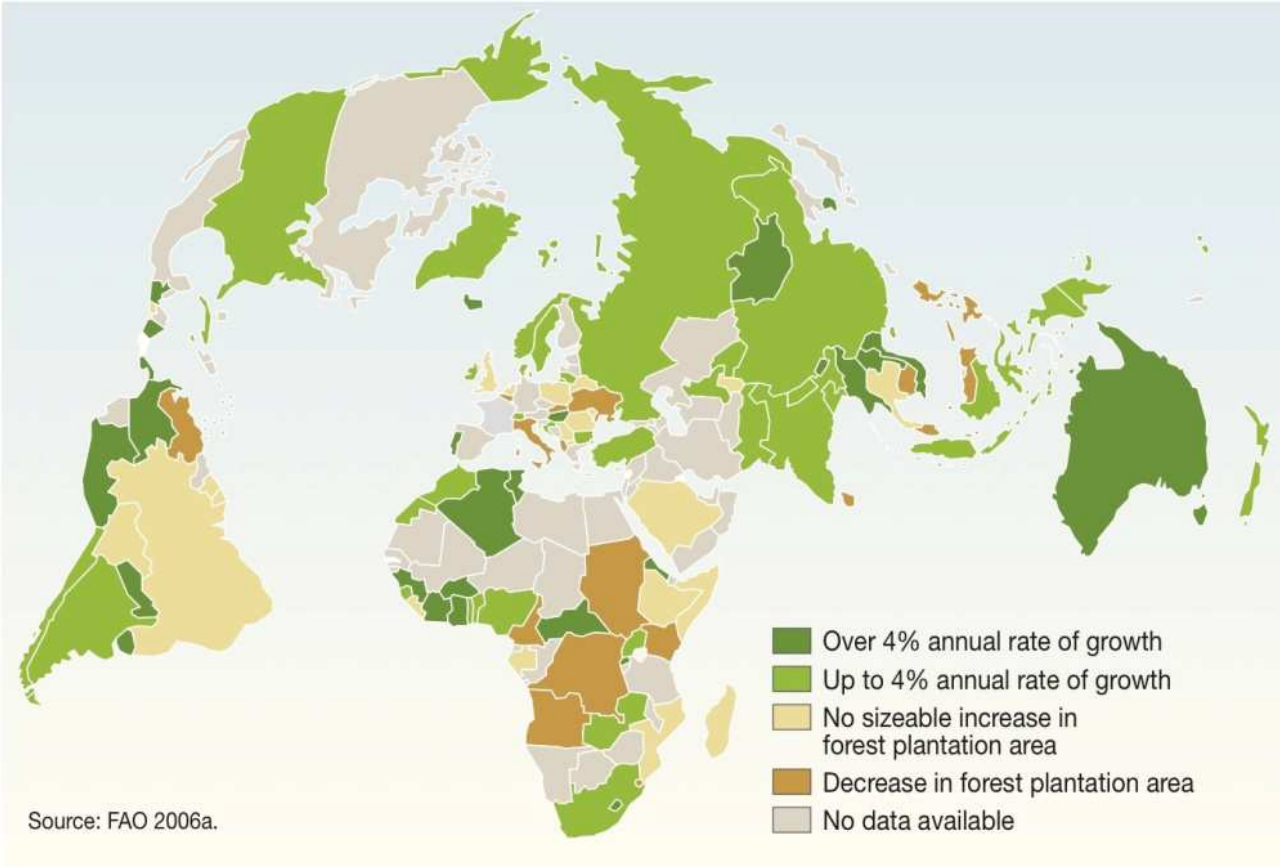

Figure 3. Changes in the area of productive forest plantation (GRID-Arendal 2013), http://www.grida.no/graphicslib/detail/changes-in-area-of-productive-forest-plantations_bdaf*. Credited Philippe Rekacewicz assisted by Cecile Marin, Agnes Stienne, Guilio Frigieri, Riccardo Pravettoni, Laura Margueritte and Marion Lecoquierre.*

5.3. Types of wood fuels

Wood fuels can be separated into primary, secondary and tertiary wood fuels (Figure 4). Primary wood fuels are the main product from energy forest, whereas it is usually a side product or sometimes one of more main products from conventional forests, that more typically has timber and pulpwood as their main products. Fast growing trees species grown in plantation or coppice systems, such as poplar, eucalypt and robinia, are also harvested as timber or pulp wood, and as such, energy wood may be a side product from these plantations as well. Secondary wood fuels are residues from the industry, and tertiary wood fuels are used wood that has already served its primary purpose(s).

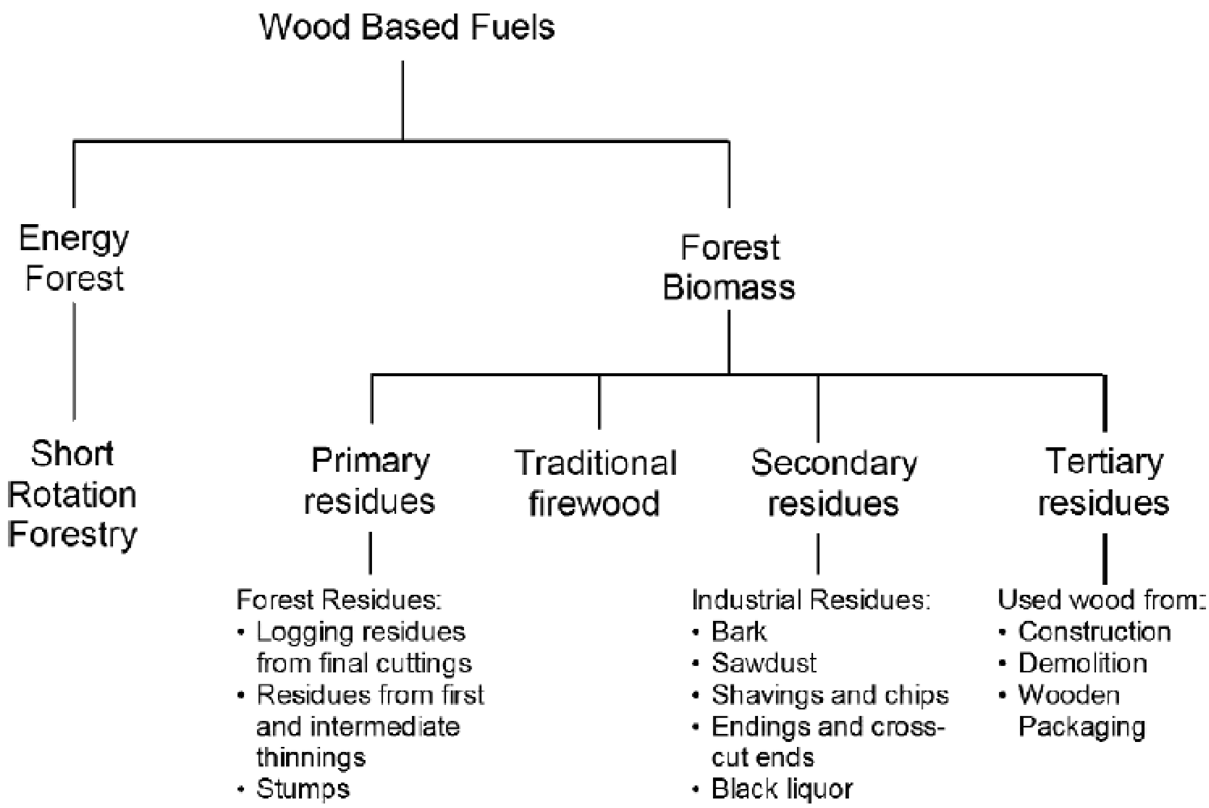

Figure 4. Classification of wood fuels. From Röser, Asikainen et al. (2008) figure 2.1.

(Mantau 2012) gives an overview of wood flows at the European level (EU27), including round wood, primary and secondary residues (Figure 5). The raw material for primary, secondary and tertiary wood fuels has usually been produced in the same types of production systems and on the same lands, with the basic sustainability concerns being identical. However, difficulties with tracking the material and its origin increases from primary to secondary and finally to tertiary wood fuels, which often has a long history and several uses between production of the wood in the forest and its final use for energy purposes.

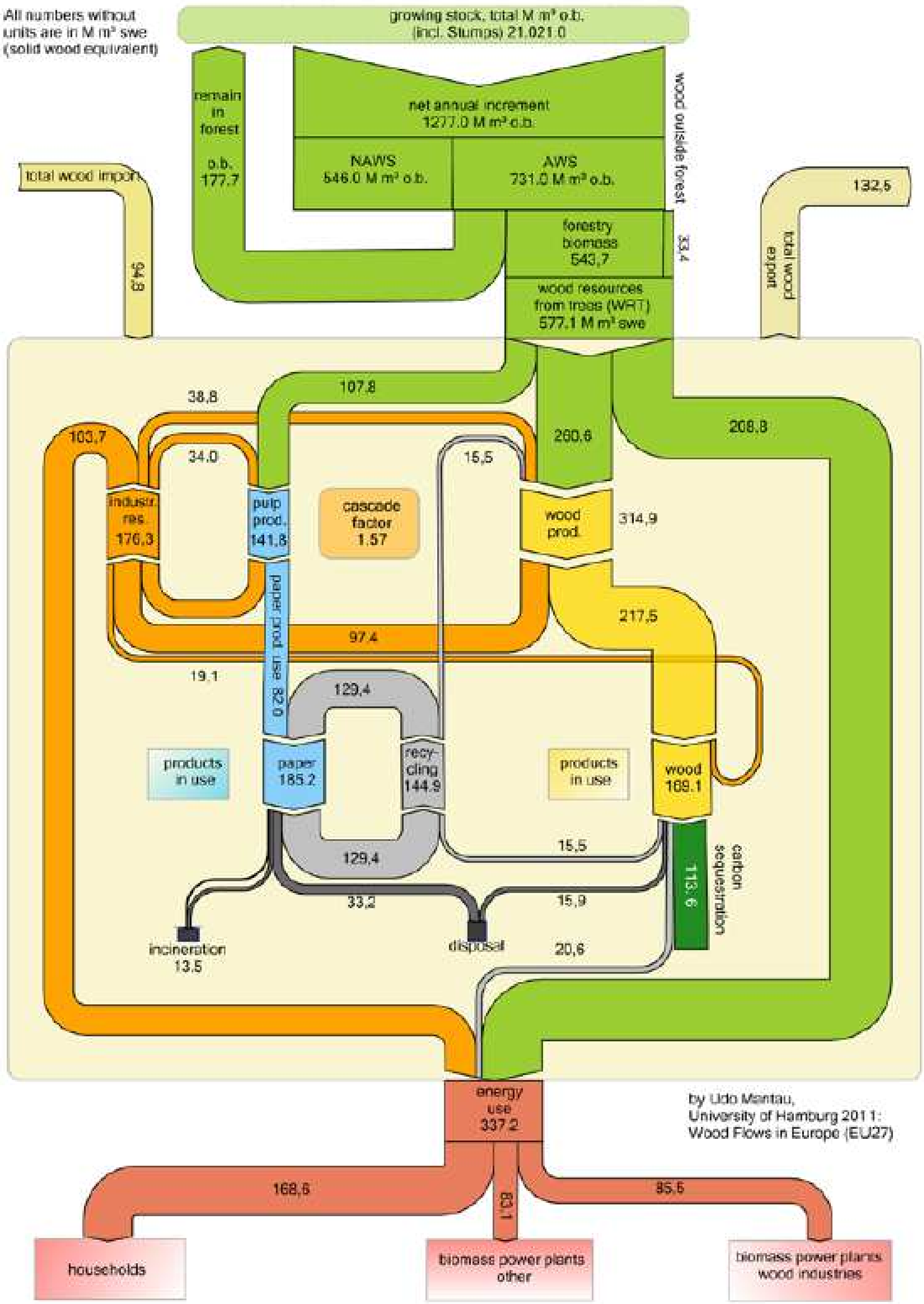

Figure 5. Condensed wood flow chart for EU27 ((Mantau 2012), figure 1). A more detailed flow chart is also available from the same information source.

5.4. Wood fuel supply chains

Sustainability aspects also exist for the whole supply chain, especially with regard to the greenhouse gas emissions. Wood fuel supply chains may be local, national, regional or global, and they may deal with different types of fuel and sources of the feedstock and as a consequence, the number of involved actors and the complexity of their interaction vary (Stupak, Hoekstra et al. 2009). Two examples of simplified supply chains are illustrated in Figure 6 and Figure 7.

Occasionally, the whole supply chain for primary wood fuels is contained within one company. For example, Stora Enso and UPM Kymmene own forests, saw mills and industrial energy plants for heating. More often, the supply chain includes at least two independent economic operators, which are the forest or land owner and the energy plant. Contractors may be involved in harvesting, forwarding, transport, and chipping (Stupak, Hoekstra et al. 2009).

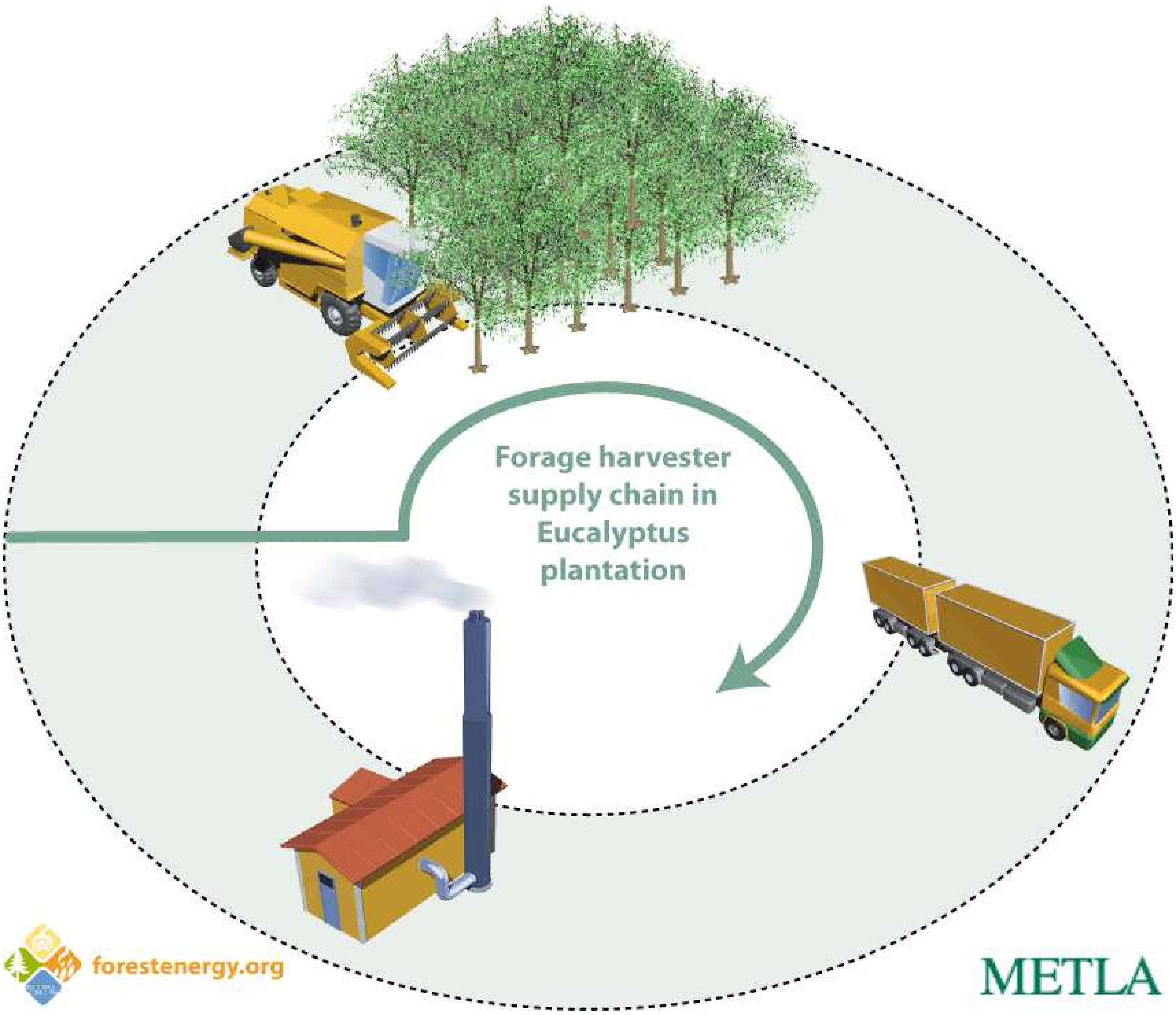

Figure 6. Simple supply local chain, with an energy plantation delivering biomass feedstock for an energy plant (http://www.forestenergy.org/pages/images/).

Supply chains are even more complex for secondary and tertiary wood fuels. Producers of secondary wood fuels include sawmills, carpentry industry, plywood mills and other panel industry, and chemical and mechanical pulp mills (Peksa-Blanchard, Dolzan et al. 2007), and the supply chains may also involve pellet and briquette producers, traders, whole-sales, retailers etc. even these fuels are also often used by the industry itself to produce heat and/or electricity (Stupak, Hoekstra et al. 2009).

Figure 7. Local supply chain involving only one forest, a saw mill and an energy plant, with harvesting residues and stumps being used for energy. Usually more suppliers deliver to one plant and in the case of large forest companies with geographically spread forest properties. They may also deliver forest biomass for several plants (http://www.forestenergy.org/pages/images/).

Tertiary wood fuel sources are typically wood from construction and demolition, packaging, other industries, and household wastes, or it is a component in industrial and household wastes. In the Netherlands, household wastes, including wood components, are collected by municipalities, while commercial wastes are probably collected by producers or other commercial actors. These wastes are processed in waste incinerators or compost installations, or stored in landfills (EUBIONET 2007).

Sustainability issues become increasingly complex the more actors that are involved, the more transport and storage that is involved, the longer the time lapse there is between cutting the wood and using it for energy purposes, and the longer the cascade of different uses since cutting.

6. Forests and wood production in a global perspective

Knowledge about different climatic and ecological baseline conditions is crucial to understand the environmental sustainability impacts surrounding bioenergy feedstock production from forest. The amount of resources that are physically available may not always be technically or economically available, or available from an environmental point of view (European Environment Agency 2006, Schubert, Schellnhuber et al. 2009, Rettenmaier, Schorb et al. 2010, Bentsen and Felby 2012). In this section we review basic global information about the forests, and briefly introduce which forest ecosystem types exist in different climatic zones. Some of these forest ecosystems may potentially contribute to current and future sources of wood biomass to meet the global as well as the Danish energy demand, even if some are more likely to contribute compared to others.

6.1. Forest biomes and other land uses

The world's forests are separated into in different biomes (Figure 8). Although there is significant variation within a certain biome, each of them possesses a number of general traits. The boreal zone is characterised by low growth rates, while the temperate zone ecosystems have higher production rates and are, in general, more resilient. The tropical zone is characterised by potentially high growth rates, but also by very old and degraded soils vulnerable to disturbance.

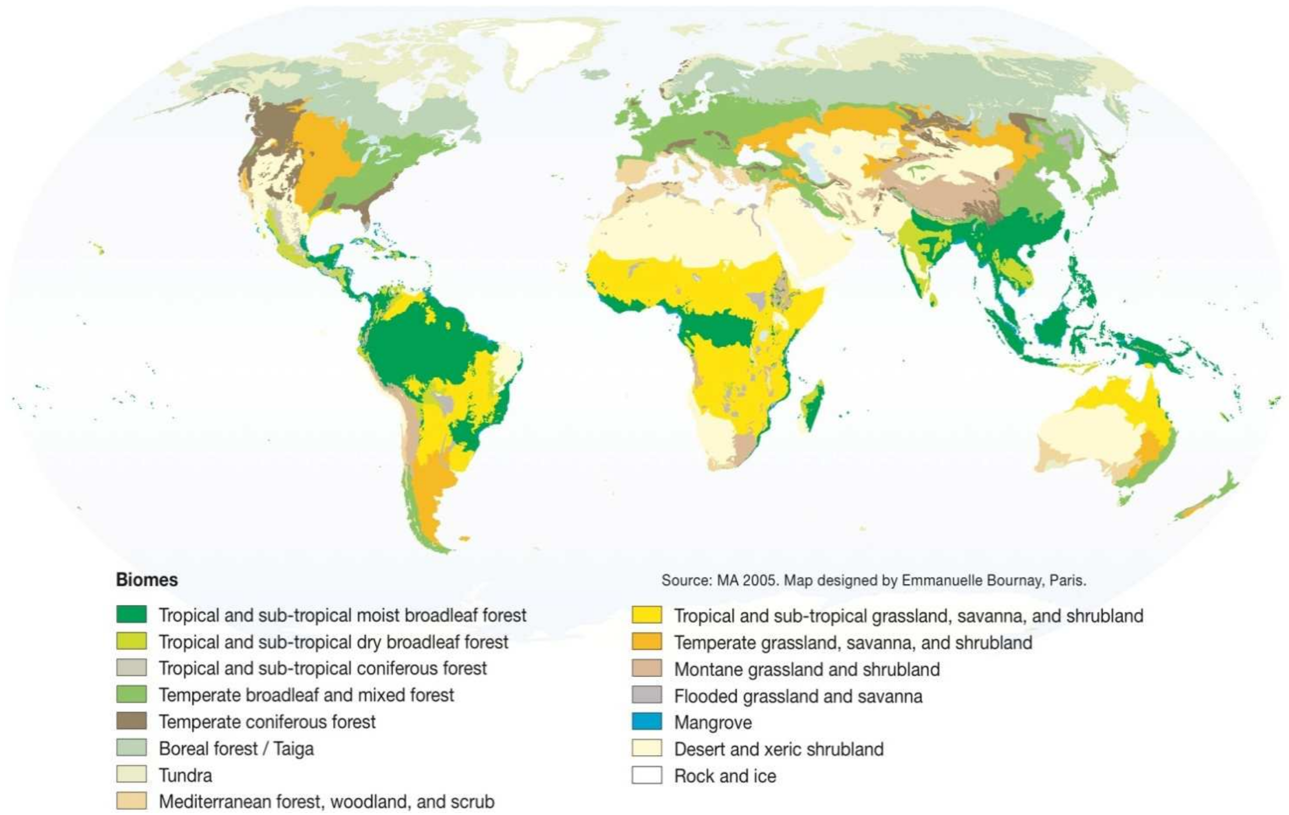

Figure 8. Vegetation zones (biomes) of the world (GRID-Arendal 2013), http://www.grida.no/graphicslib/detail/the-main-biomes-of-the-world_f8c1. Credited Philippe Rekacewicz assisted by Cecile Marin, Agnes Stienne, Guilio Frigieri, Riccardo Pravettoni, Laura Margueritte and Marion Lecoquierre.

The land resource base differs among regions in terms of size and composition (Figure 9). Eastern, Southern, Western Africa and Southern and Western Europe are characterised by a high proportion of agricultural land, while Central Africa, South America, Eastern and Northern Europe particularly are dominated by forest lands.

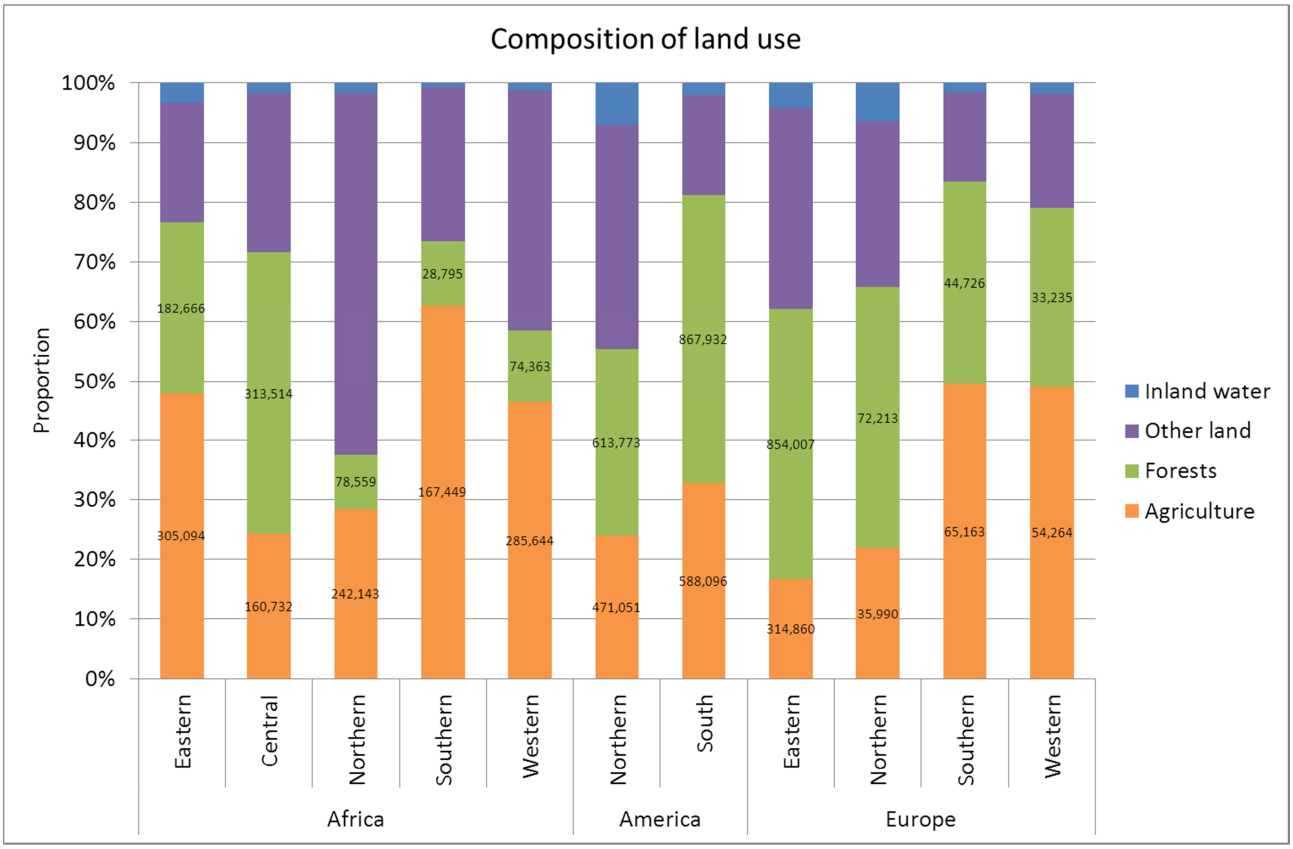

Figure 9. Composition of land use in selected regions. The bars illustrate the relative allocation of land to agriculture, forests, other land (e.g. desert, tundra, cities and infrastructure) and inland water (i.e. lakes and rivers). Numbers on the bars present the area of agricultural and forest land respectively in 1000 ha (FAO 2010).

6.2. Development in forest area

The forest area has undergone considerable changes over time. In average the world has lost 6.4 million ha of forest annually from 1990 to 2011, which is about 0.2% of the world's total forest area (4,027 million hectares in 2011) (FAO 2010, FAO 2012). This average loss covers a considerable regional variation (Figure 10). Among the regions selected for this study, there is a significant decrease in the forest area of South America; 3.9 million ha annually. Considerable deforestation also takes place in some parts of Africa, particularly in east, central and West Africa. In total in Africa 3.6 million ha of forest has been converted annually to other uses since 1990. North America and most parts of Europe currently see the opposite development. In North America and Southern Europe, the forest area has increased by 250,000–450,000 ha annually since 1990. Asian countries are not shown in Figure 10, but in e.g. South East Asia large forest areas have been cleared, while the forest area has increased considerably in e.g. Eastern Asia due to large afforestation programmes in China (FAO 2010).

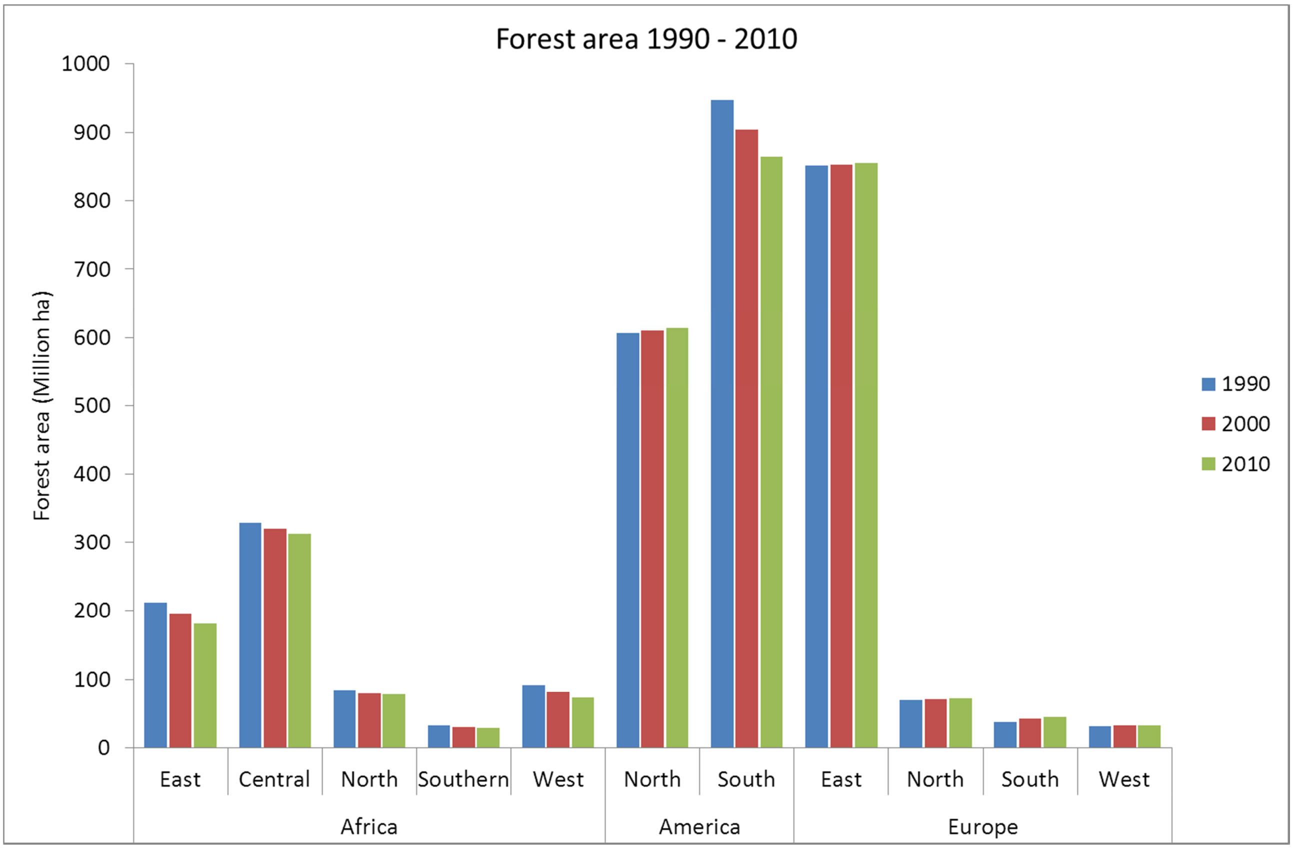

Figure 10. Forest area in selected regions in 1990, 2000 and 2010 (FAO 2010).

Previously, the situation in Europe and North America was similar to the current situation in South America and Africa (Figure 11). In Europe, much deforestation took place before 1855. For example, the Danish forest area was at its lowest in 1805, with only 2-3 % of the land being covered by forest at that time.

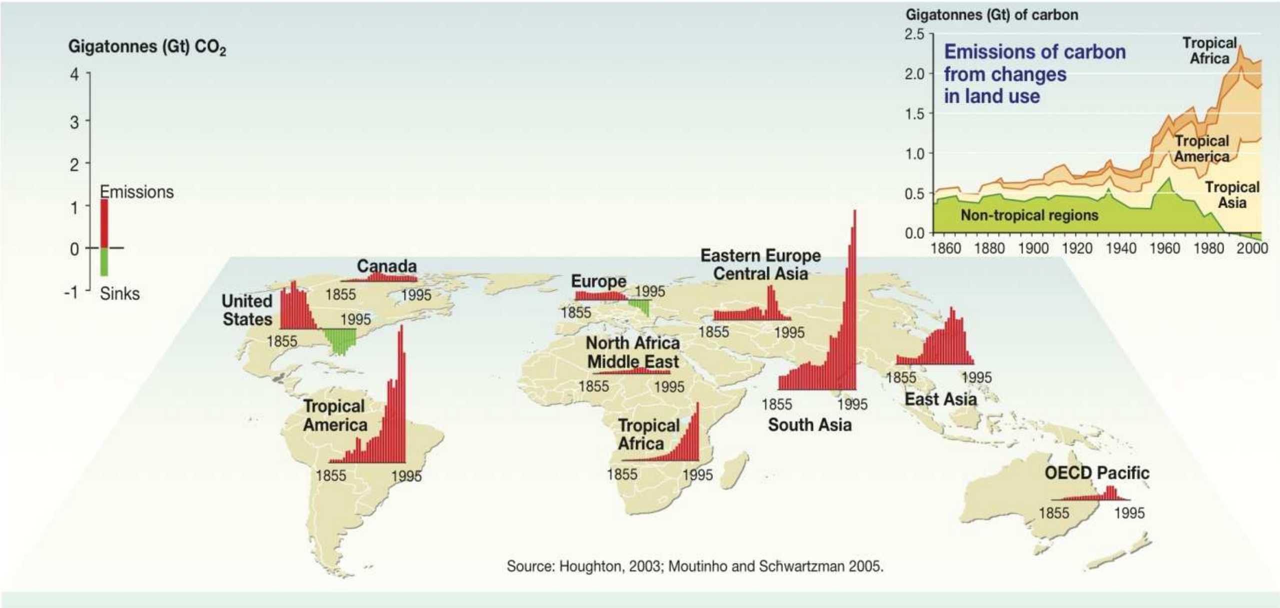

Figure 11. Net emissions from forests in different regions of the world during the period 1855-1995 (UNEP, FAO et al. 2009). The net emissions largely express the changes in the forest area.

6.3. Forest management and unmanaged forest

Among the regions selected for this study, forests are predominantly located in Northern and South America and in Eastern Europe (Figure 12). In Eastern Europe it is particularly the vast forests of Russia that makes this region one of the most forested in Europe. The regions that have the largest forest resources also have a relatively high proportion of primary forest, i.e. forest of native species with no indications of forest management activities taking place (FAO 2010). In most regions, however, naturally regenerated forests (forests that regenerate naturally but are under some level of forest management) dominate the picture. Particularly in the forests of Northern, Southern and Western Europe, planting or seeding play a large role in forest regeneration, whereas primary forests are practically non-existing. At the global level, in average 36 % of the forested land is classified as primary forest, 57 % as naturally regenerated forest and 7 % as planted or seeded forest (FAO 2010).

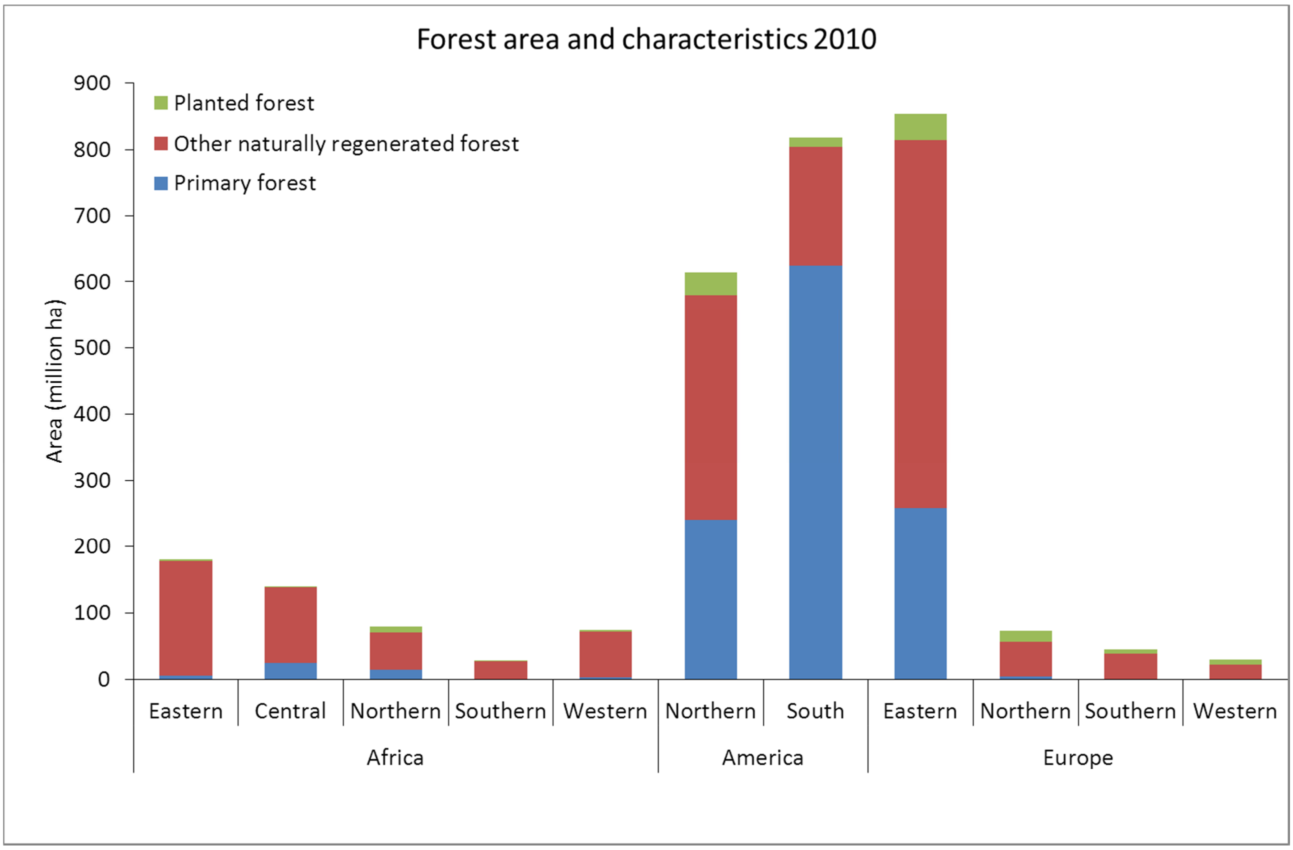

Figure 12. Forest area and the allocation of forest area to primary forest, naturally regenerated forest and planted forest in 2010 (FAO 2010).

6.4. Wood production

At the global scale, the production of industrial wood and woodfuels has increased during the last 50 years. The production of industrial wood appear more volatile than the production of fuelwood. Industrial wood demand is tighter linked to the economic development and situation in general, whereas a major part of fuelwood production at the glocal level is linked to subsistence usages.

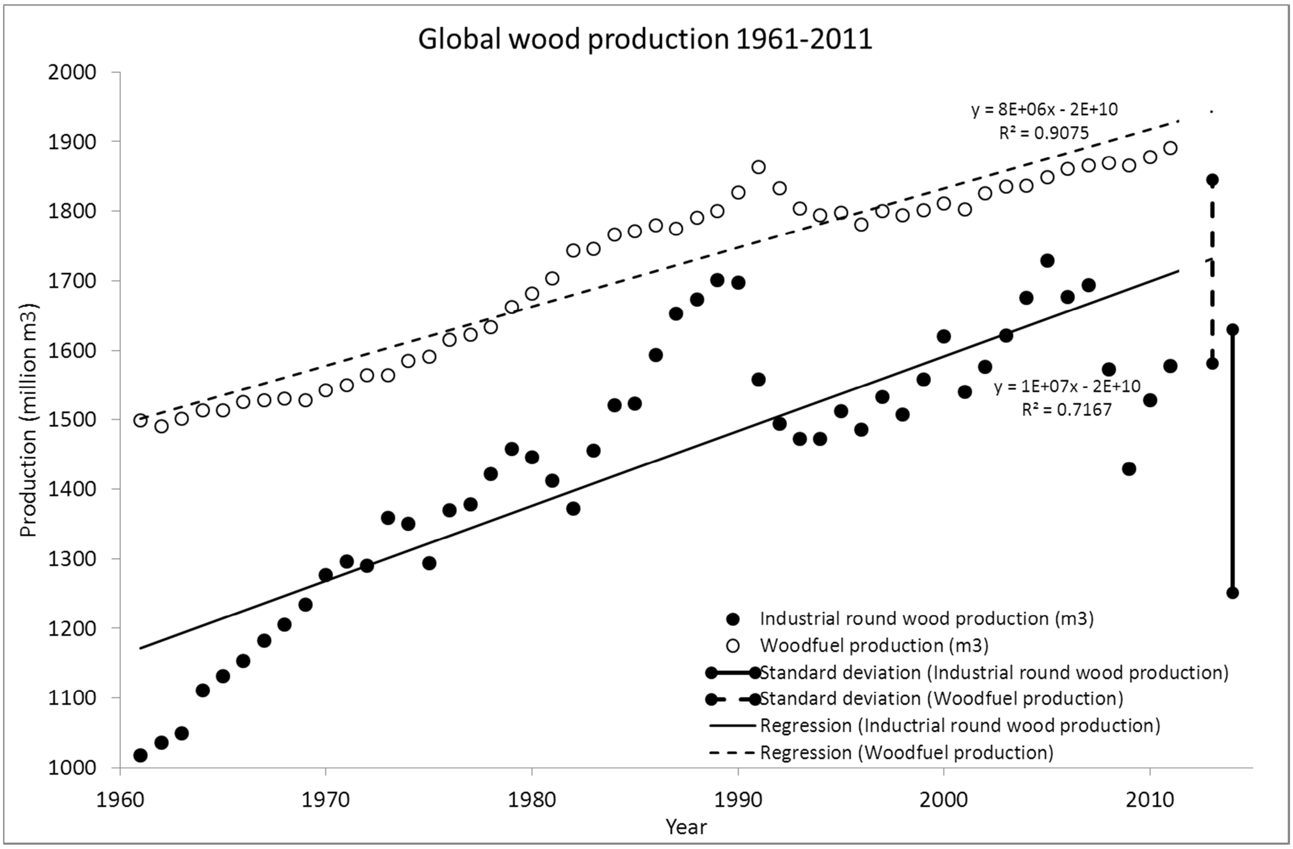

Figure 13. Global production of industrial round wood and wood fuel from 1961 to 2011. Vertical lines in the right part of the graph indicate the variability in production levels of industrial round wood and fuel wood respectively. Own calculations based on data from FAOSTAT (FAO 2012).

Wood production has generally increased since 1990 in the regions selected for this survey, with a few exeptions. In most African regions fuelwood production has increased both during the period 1990-2000, and during the subsequent period from 2000-2005 (Figure 14). Particularly in Eastern Africa, the fuelwood production increased by 12-13 million m^3 annually from 1990-2000 and 6 million m^3 from 2000-2005. In Eastern Europe a significant drop in industrial wood prodution took place in 1990-2000, 15 million m^3 annually. During the subsequent period, the industrial wood production increased again with close to 10 million m^3 annually.

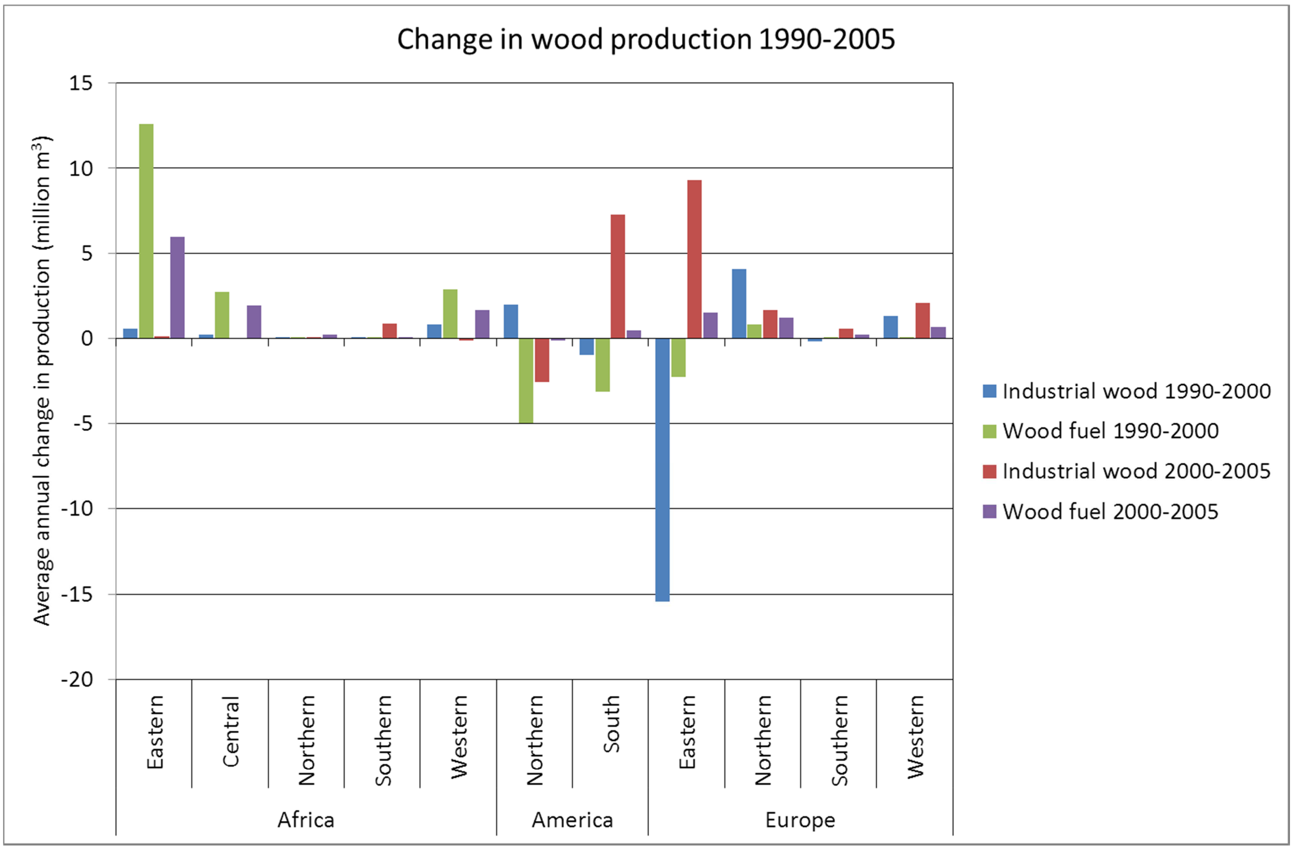

Figure 14. Average annual change in production of industrial wood and wood fuel respectively in selected regions from 1990 to 2000 and from 2000 to 2005. Own calculations based on data from FAOSTAT (FAO 2010).

7. International trade and demand

7.1. Global trade and future demands

Until a decade ago, the use of wood for energy was largely a local issue, with the energy wood being consumed within a relatively short distance from the forest where it was harvested. Finnish studies show that truck-based transportation of forest fuels is still only economically profitable within a 100 km distance from the plant (Ranta and Korpinen 2011). At longer distances, railway infrastructure or access to water transportation is needed for a cost-efficient transportation (Tahvanainen and Anttila 2011). However, the use of saw dust from saw mills to produce pellets, with long distance sea transportation involved, has shown to be economically profitable and the global trade with wood and wood derived biomass fuel products is increasing, now making up a significant share of the global trade of biomass for energy purposes (Lamers, Junginger et al. 2012).

The analysis by Lamers et al. (2012) shows that cross-border trade of biomass for energy has grown from 56 PJ in 2000 to 300 PJ in 2010. During that period, the trade of wood pellets grew most, from 8.5 PJ in 2000 to 120 PJ in 2010, while the trade with wood chips constitute the largest amount by weight. In 2009 the world production of wood chips was assessed to be 59 million tonnes fresh weight (~549 PJ) of which 25-26 million tonnes (~233-242 PJ) were cross-border traded (Lamers, Junginger et al. 2012).

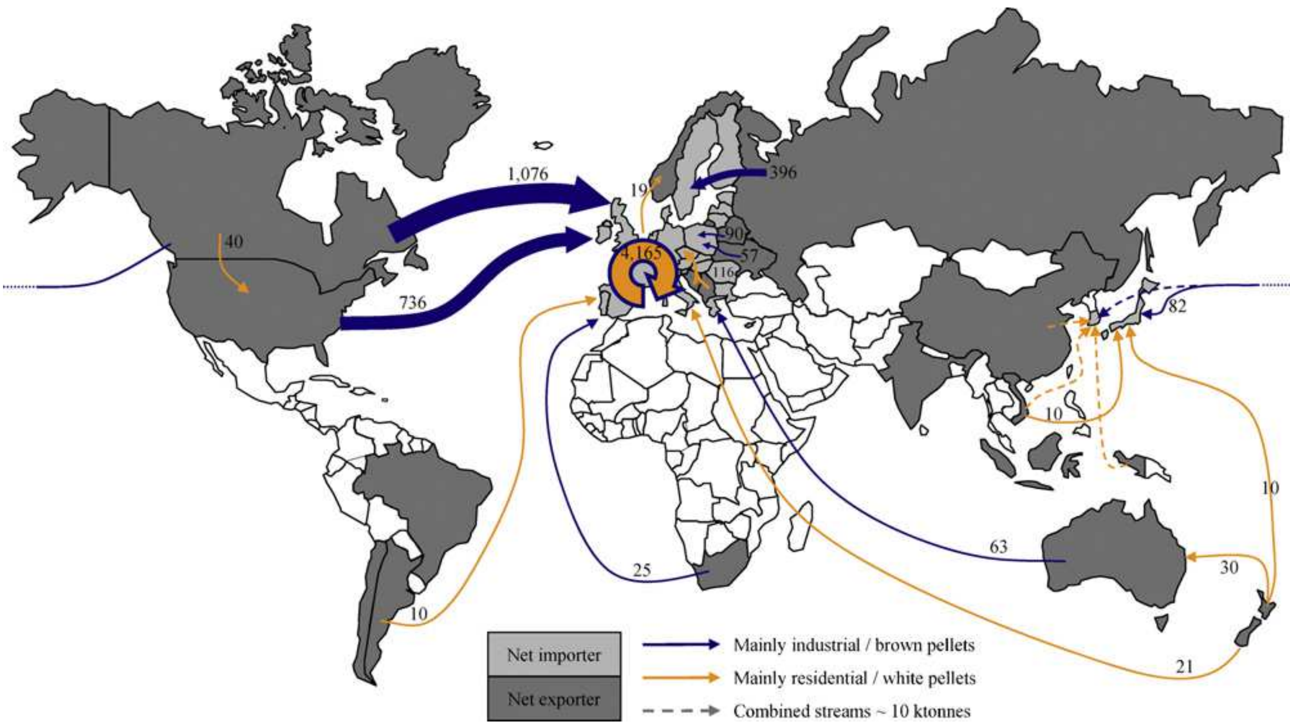

Figure 15. World wood pellet trade streams above 10 ktons in 2010 (Lamers, Junginger et al. 2012).

Corresponding data for the global wood pellet production that was traded in 2010 are 16 million tonnes fresh weight (~280 PJ). In 2010 the intra-EU trade constituted 62 % of the global trade of wood pellets (Sikkema, Junginger et al. 2010), with Germany, Austria, Latvia, Estonia, Russia and Portugal being the largest exporters, and the Netherlands, Denmark, Belgium, Italy, Sweden and Austria being the largest importers (Figure 16).

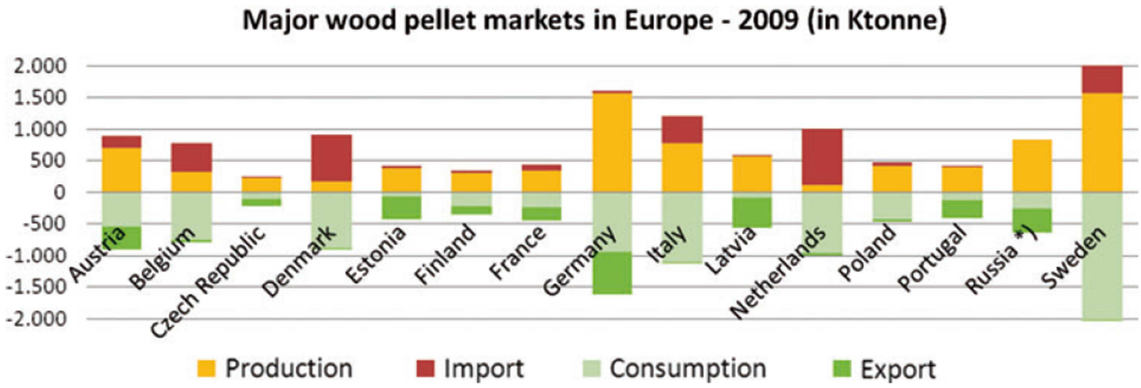

Figure 16. Balance of pellet volumes for the major European country markets in 2009 (Sikkema, Junginger et al. 2010)

The global trade with round wood and paper products is still substantially larger than the trade with wood pellets and chips. Cross border trade with round wood amounts to 80-90 million tonnes fresh weight (~740-840 PJ) annually and paper and paper products amounts to approximately 110 million tonnes (FAO 2012).

Projected European demands for biomass for energy till 2020 varies considerably. Joudry et al. gives an overview of projections for solid wood biomass demands ranging from 35–315 million tons yr^{-1} (Joudrey, McDow et al. 2012). Based on NREAP's Bentsen and Felby estimate the biomass demand for all energy purposes (solid, liquid and gaseous) from both forests and agriculture to reach 10 EJ yr^{-1} in the EU by 2020 (Bentsen and Felby 2012).

7.2. Current sources of the Danish wood fuel imports

There are two sources of data for biomass imports to Denmark. The national foreign trade statistic (Danmarks Statistik 2012) is based on companies' own reporting and information from tax authorities. The statistic is subject to incompleteness due to a minimum threshold reporting obligation. Companies importing goods of a value less than 3.7 million DKK (in 2012) are not obliged to report to Statistics Denmark. The Danish Energy Authority make their own statistic on imported wood chips and pellets (Energistyrelsen 2012). The energy statistic is based on interviews and expert evaluations. Discrepancies appear between the two statistics.

Data presented in figures 17-20 are based on the foreign trade statistic which reports the amounts imported from different countries. From 2009 to 2011 the import of wood pellets increased from 15 to 34 PJ (Danmarks Statistik 2012). Wood pellets are sourced from a larger number of countries, with the 20 largest contributors to the Danish import (Figure 17) accounting for 99.2-99.9 % of the imported amount in the period 2009-11.

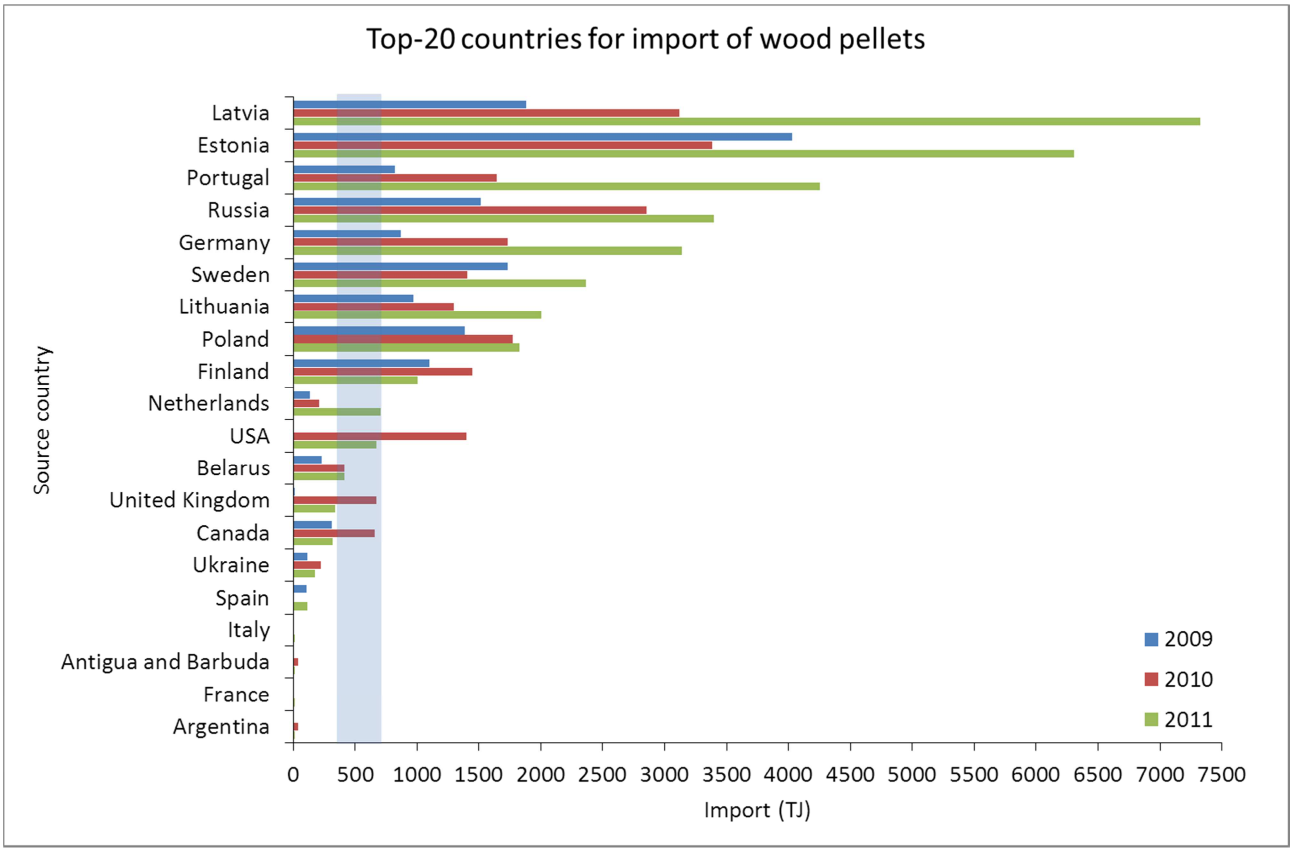

Figure 17. Imported quantities of wood pellets from the 20 largest source countries in 2009-2011. The shaded area represents the quantity of a typical shipload of wood pellets (350-700 TJ or 20-40 million kg).

The relative dominance of individual source countries varies from year to year (Figure 18), but for the period 2009-2011 the Baltic States, Portugal, Russia, Germany and Sweden have generally been dominating source countries on the Danish wood pellet market.

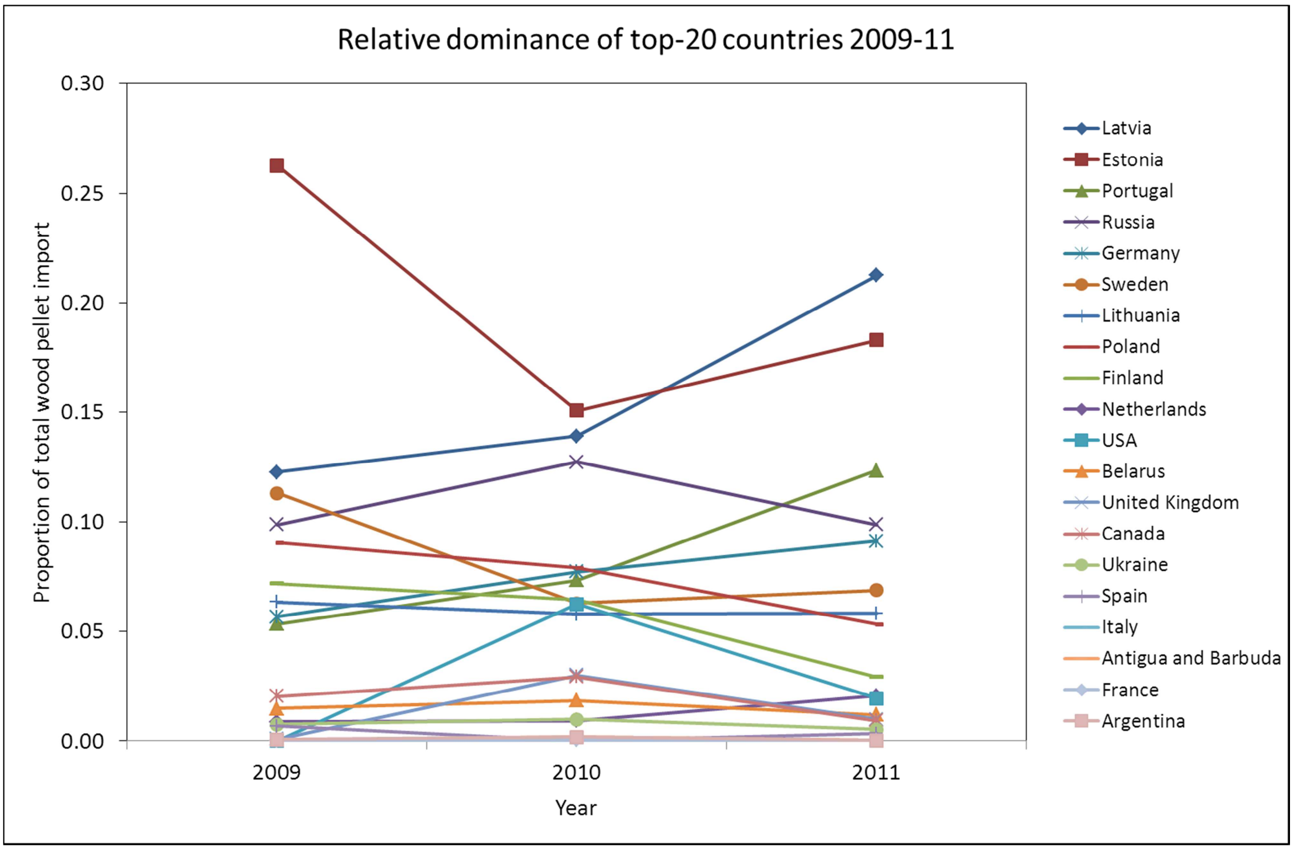

Figure 18. Relative dominance of individual source countries to the Danish import of wood pellets in 2009-11 (Danmarks Statistik 2012).

The amount of wood chips imported to Denmark is more volatile than the amount of wood pellets (Figure 19). In 2011 the total import amounted to 3.1 PJ (or 5.8 PJ according to the energy statistics (Energistyrelsen 2012).

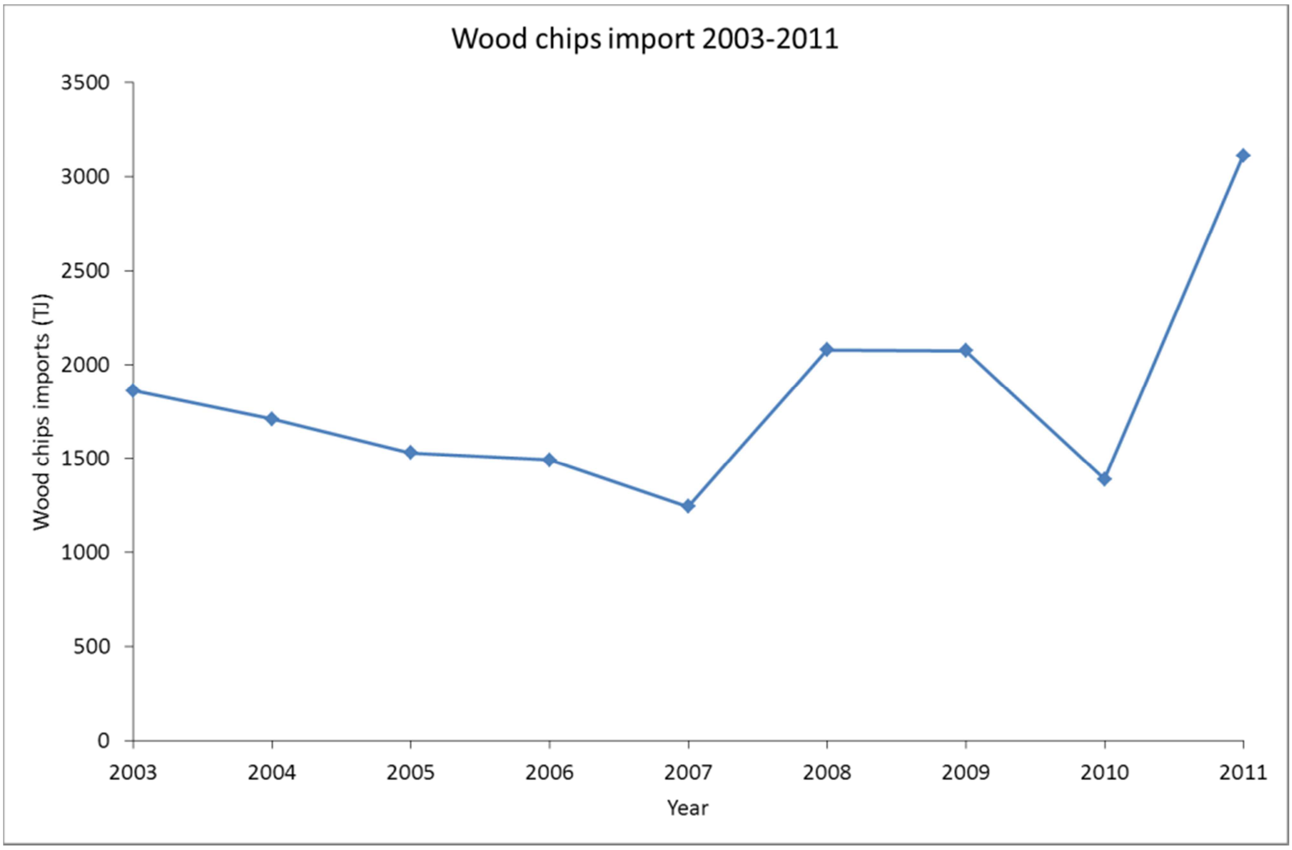

Figure 19. Wood chips import to Denmark 2003-11 based on the foreign trade statistics of Statistics Denmark (Danmarks Statistik 2012).

Also wood chips are sourced from a large range of countries (Figure 20), with Sweden, the Baltic States, Germany and Poland being major and consistent source countries. In 2011 the largest amount was sourced from Liberia. In the preceding two years practically nothing was sourced from Liberia. The import from Liberia is specifically associated with Vattenfalls engagement in Buchanan Renewables in Liberia. Vattenfall terminated their partnership with Buchanan Renewables in May 2012.

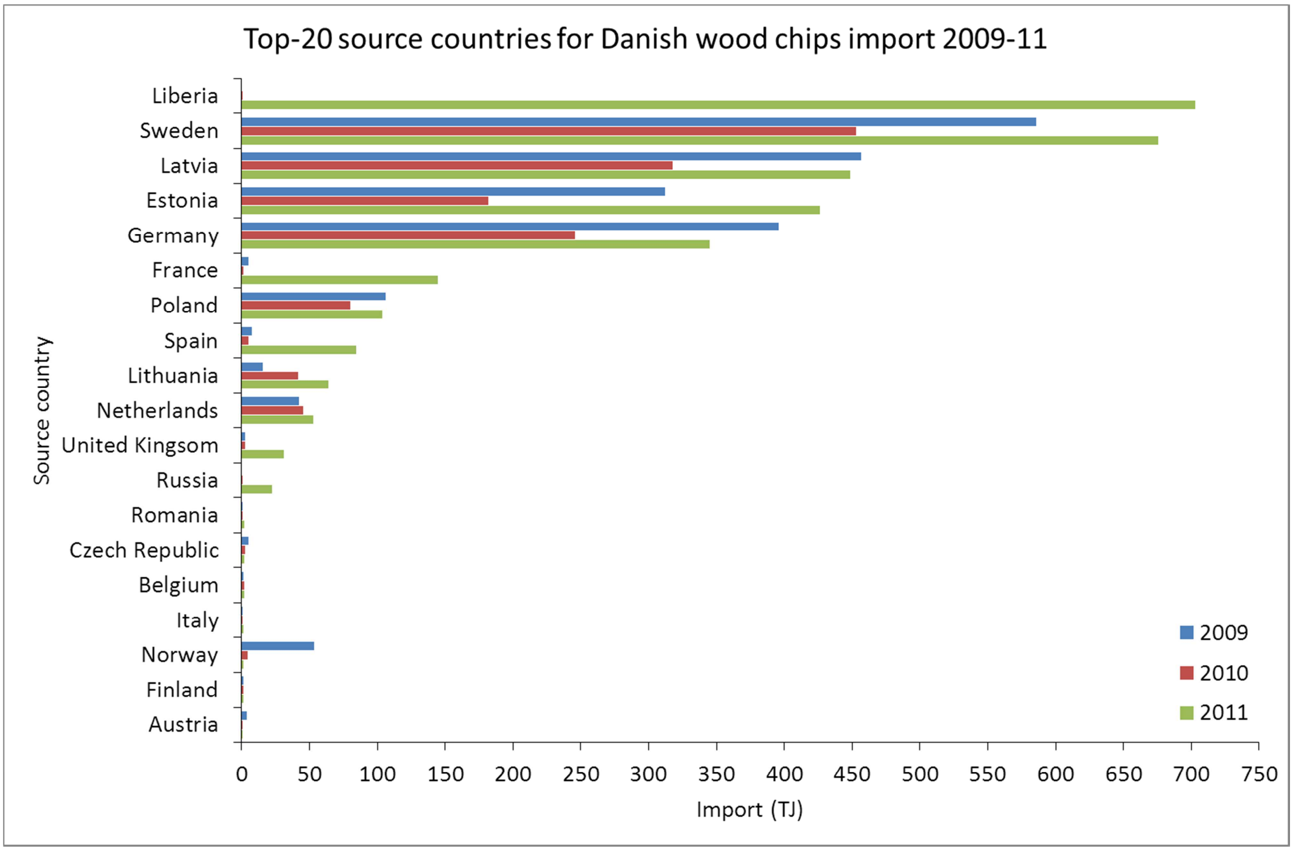

Figure 20. The 20 largest sources of Danish wood chips import (2009-11). Based on Statistics Denmark (Danmarks Statistik 2012).

7.3. Possible future source countries of Danish wood fuel imports

The location of the world's forest resources is an indication of where future Danish wood fuel imports could be sourced. A detailed study on future sourcing of wood pellets was performed by Pöyry in 2011 indicated that near term pellet production may increase in several parts of the world (Figure 21).

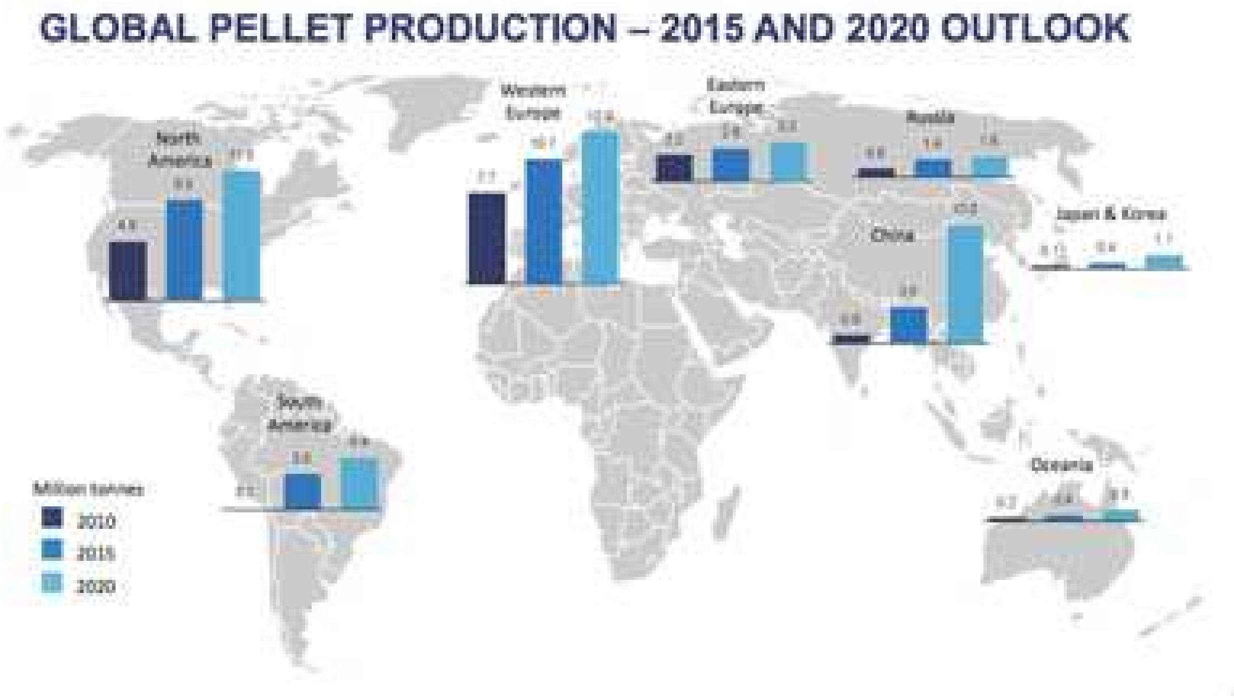

Figure 21. Global pellet production outlook (Pöyry 2011).

In order to get information on which sources that are most likely to be imported in Denmark we conducted a brief survey among the major biomass importing organisations in Denmark. Their input might be an indication of the economic, social or environmental constraints surrounding potential wood fuel sources.

The survey showed that future sourcing of biomass for the energy sector is likely, to an even higher extent than currently, to be directed towards wood pellets. The current primary source countries were also seen as the primary future sources in the short term; these include the Baltic States, Russia, Poland, Germany and Sweden, and Southern Europe (Portugal and Spain).

Larger imports from overseas countries were also expected in the short term, predominantly from USA and Canada. In a longer time perspective, overseas sources are expected to gain in importance. Further development of production in the eastern part of North America (South eastern states of USA and Eastern states of Canada) is expected to create new possibilities for supplies. This was also the case for the eastern part of South America, probably with emphasis on Brazil, and the western part of Africa (Ghana, Liberia, Ivory Coast).

7.4. Current and future wood fuel feed stocks

Wood pellets have traditionally been produced from residual biomass (saw dust, shavings etc.) from wood industries (secondary residues cf. Figure 4). Pellet production has thus displaced on-site combustion for process heat generation or landfilling and natural decomposition. Scenarios for future supply chains suggest not only an increased pellet production but also a shift from secondary residues as feedstock towards primary residues (logging residues) or primary wood resources (Figure 22) (Cocchi, Nikolaisen et al. 2011). In the estimated development till 2020 particularly the pine forests of Southeast U.S.A., forest plantations in Brazil (pine, eucalypt) and mountain pine beetle killed forest in western Canada is anticipated to contribute to the future resource base. In South-eastern US, pellet plants already compete with the pulp and paper industry for pulpwood (Fledderman 2013), and there is an example that an old bottomland hardwood swamp has been harvested for pellet production (Carr 2013).

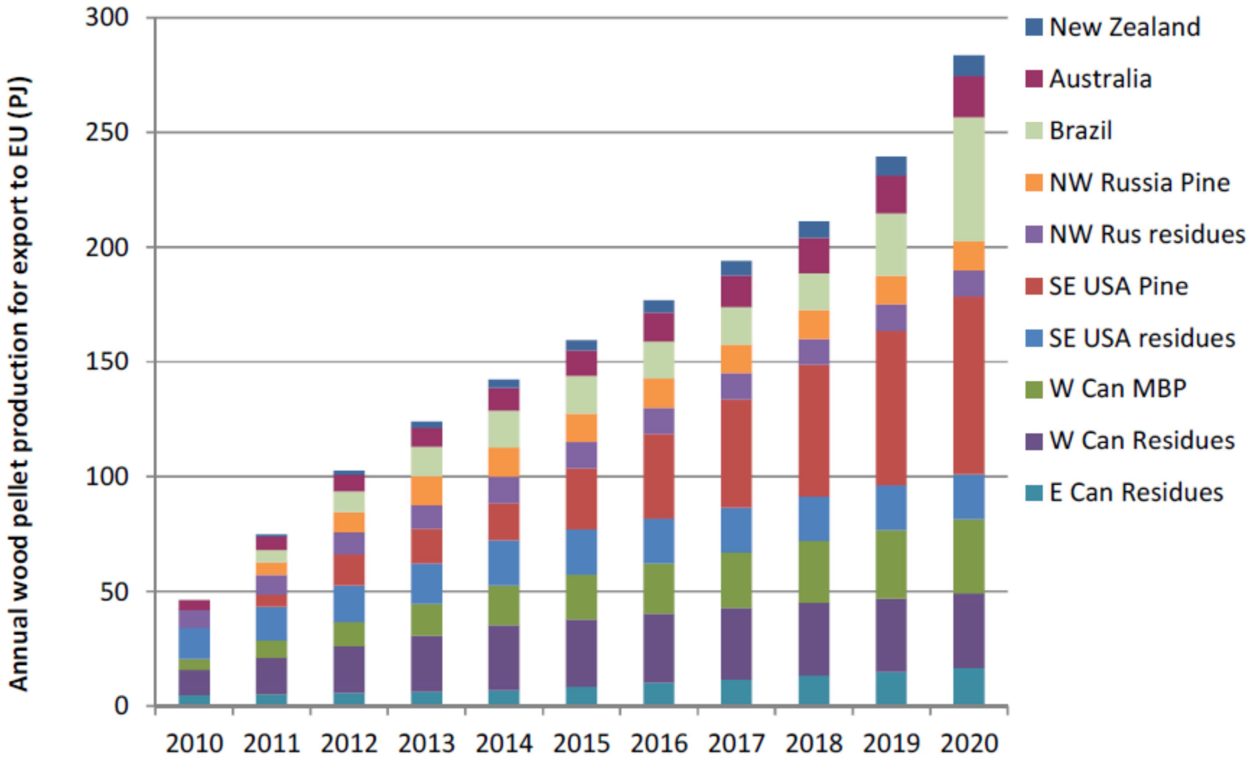

Figure 22. Anticipated growth in available solid biomass supply from the various sourcing regions. Residues = wood industry residues (e.g. saw dust), MPB= Mountain pine beetle affected wood. From(Cocchi, Nikolaisen et al. 2011), figure 1.9.

The shift in the type of feedstock for wood pellets is partly caused by a shift in the consumption pattern. An increasing part of the pellets are sourced for utility companies rather than for residential heating. Utility companies require a higher degree of supply security and the trade is based on longer contracts. This forces the pellet producers to secure their resource base further. The amount of secondary residues available is closely linked to production levels in the wood industry, which are volatile. The need to secure the resource base shifts the focus of the pellet producers to a variety of wood sources, hereunder primary wood resources (Cocchi, Nikolaisen et al. 2011). Sourcing prospects for individual countries and regions are further described in the chapters that are specific for each region.

The wood chips feedstock can be primary stem wood (e.g. eucalypt managed in short rotation in southern Europe), primary residues (logging residues and early thinnings of forest stands), or tertiary residues (waste wood) (Lamers, Junginger et al. 2012). Wood chips are usually traded over shorter distances than wood pellets due to lower bulk density and higher moisture content and thus lower energy density.

8. Sustainability issues for wood fuels

Sustainability concerns over bioenergy feedstock production have mainly been a national concern until about a decade ago, when the international trade with biomass feedstock, including wood fuels, took off. The international trade has increased concerns for biomass sustainability abroad in source countries. According to (Kittler, Price et al. 2012), importing European bioenergy companies often view the sustainability of their biomass supply as the largest not quantified risk to their business. At the same time, wood pellet and chip producers are concerned if the biomass feedstock available to them will meet the sustainability requirements of the wood fuel importing countries.

In this chapter we briefly introduce the concept of bioenergy sustainability and the specific sustainability issues identified in chapter 1: Reduction of greenhouse gas emissions, biodiversity, soil, water, and air quality, and food security.

8.1. Defining forest, biomass and bioenergy sustainability

Sustainability is commonly seen as having three overall dimensions: environmental, social, and economic sustainability, with the three dimensions being overlapping for some issues. The three dimensions are also reflected in definitions of Sustainable Forest Management (SFM). A well-recognised definition of SFM, well in line other international definitions of SFM, was developed for Europe by the second Ministerial Conference on the Protection of Forests in Europe (MCPFE) in Helsinki in 1993 (MCPFE 1993):

"*The stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biological diversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological economic and social functions, at local, national and global levels, and that does not cause damage on other ecosystems.*"

Other international meetings and processes (see chapter 10) have described what SFM is, and there seem to be growing international consensus on its key elements, and based on the various international initiatives, FAO (www.fao.org/forestry/sfm/24447/en/) have suggested seven criteria related to the following themes:

(1) Extent of forest resources;
(2) Biological diversity;
(3) Forest health and vitality;
(4) Productive functions of forest resources;
(5) Protective functions of forest resources;
(6) Socio-economic functions;
(7) Legal, policy and institutional framework

As commissioned by the Danish Energy Agency, we focus mainly on the environmental aspects of sustainability, with some more notice of food security, which is one of the most controversial socioeconomic sustainability aspects, that is outside the scope of traditional SFM frameworks.

When forests are managed for wood production they are subjected to a number of management operations that have an impact on its structures, functions, processes and populations. Sometimes the wood fuel production and/or harvesting are separate operations, or they may be integrated with other management operations. The impacts will vary with the type of feedstock and the associated the production or harvesting system (Lattimore, Smith et al. 2009, FAO 2010). Lattimore et al. (Lattimore, Smith et al. 2009) reviewed the environmental impacts associated with producing and harvesting wood for energy, including impacts on soils, hydrology and water quality, site productivity, and biodiversity.

Specific recommendations for sustainable wood fuel harvesting usually classify the forest according to a set of criteria resulting in different forest 'classes'. For some 'high risk classes' with specific values or characteristics, the impacts of wood fuel harvesting may be entirely unwanted, while different levels of restrictions then exist for other forest 'classes', according to the identified risks (Stupak, Asikainen et al. 2008). No-go areas may e.g. include e.g. un-managed forest reserves or forest on steep slopes or on soils sensitive to erosion, compaction or nutrient depletion.

A short, concise definition of sustainable biomass or sustainable bioenergy does not exist, as it does for Sustainable Forest Management. Rather, it is defined by standards set to achieve sustainable bioenergy, including biomass production, processing and end-use. A large number of actors have established such systems and standards that are useful from their purpose, and the overall sustainability issues addressed by these systems are often similar to those addressed by systems for sustainable forest management, even if there are also differences. Bioenergy-related systems especially differ with regard to inclusion of issues that extends beyond the gate of the management unit. These include greenhouse gas benefits, direct and indirect land use changes, competition for land with food production, air pollution, and e.g. water use and waste generation along the whole supply chain. See chapter 10 for further information on these systems.

8.2. Ecosystem carbon and greenhouse gas emission reductions

8.2.1. Global forest carbon pools

When the greenhouse gas impacts are compared it is important to understand the dynamics of the global carbon pools. A large part of the world's organic carbon is stored in the form or fossil fuels or gas carbohydrates (Figure 23). These fossil fuel and gas stores are usually very stable, and even if this carbon is of biological origin, the time it takes to restore it when first released into the atmosphere is very long, and in practice regarded as non-renewable.

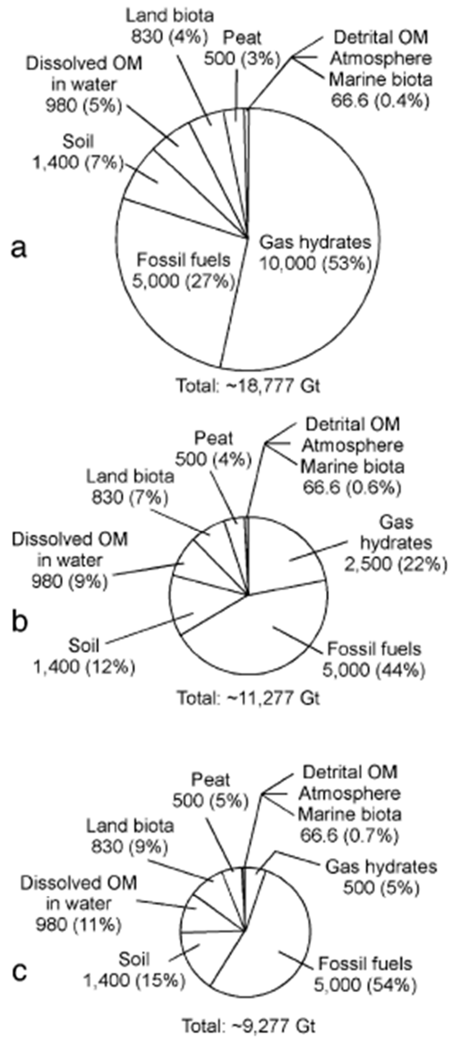

Figure 23. Different estimates of the distribution of the world's organic carbon to different pools (Milkov 2004).

The land-based ecosystem carbon pools also contribute considerably to the overall global carbon stores (Figure 23). Milkov (Milkov 2004) estimates that a total 2230 Gt carbon is stored in land biota and soil, about two thirds of these in the soil. The assessment of the total amount of carbon in living biomass is uncertain and even more so for deadwood, litter and soil carbon. (FAO 2010) estimated the total carbon reservoir in forest biomass, deadwood and litter, and soil to be 289, 72 and 292 Gtons of carbon, respectively, amounting to 653 Gt. Kasischke (Kasischke 2000) estimates storage in living forest and soil to be 258 and 941 Gt, respectively, amounting to a total of 1199 Gt. The large difference in the estimates of the soil pool may stem from differences in the soil depth to which the carbon pools were estimated. For the FAO estimates, most countries had reported carbon until 30 cm, but no adjustment was made for countries reporting to other depths.

Kasischke (Kasischke 2000) furthermore estimates that most of the global forest carbon is stored in boreal forest (59%), a large part also in tropical forest (31%), and only a smaller part in temperate forest (10%) (Figure 24), with the corresponding percentage in soil being 89%, 60% and 82%, respectively.

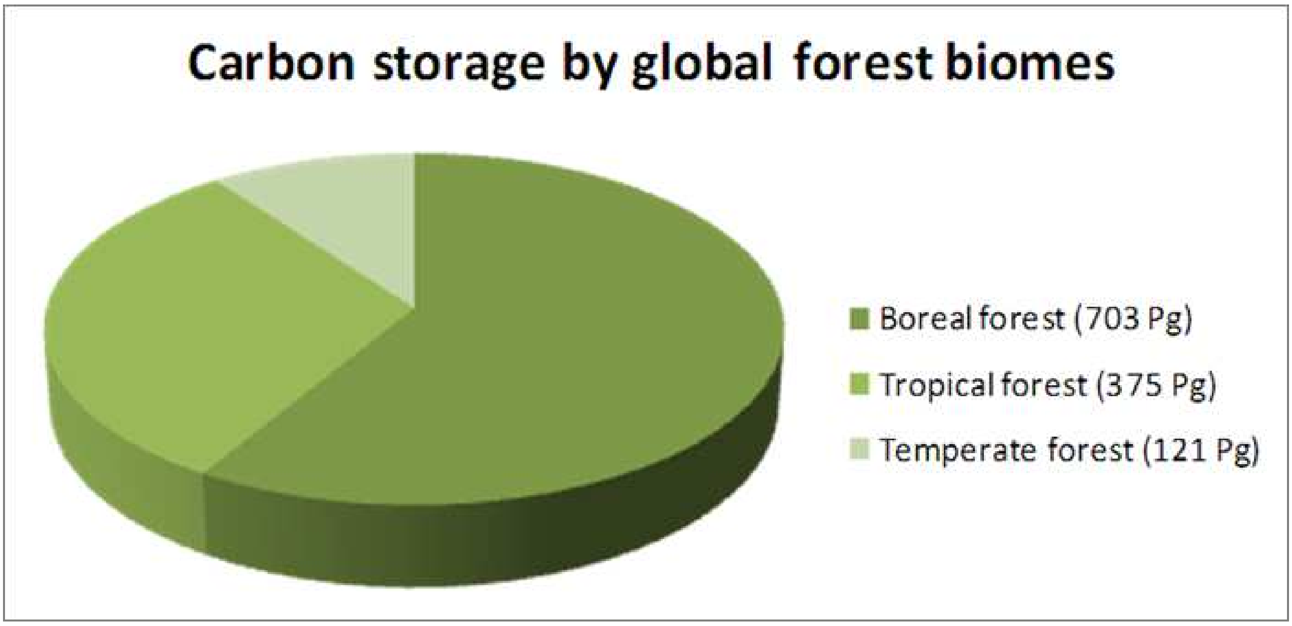

Figure 24.The amounts of carbon stored in forest biomass globally in the three main climatic zones (Carlson, Wells et al. 2009), based on (Kasischke 2000)). The total is 1199 Pg (=1199 Gtons).

Especially in boreal forests, the largest proportion of the carbon is thus stored in the soil, while in tropical forests a larger proportion is stored in the living biomass. This is also indicated in the FAO estimated distribution of forest carbon for different regions in the world (Figure 25).

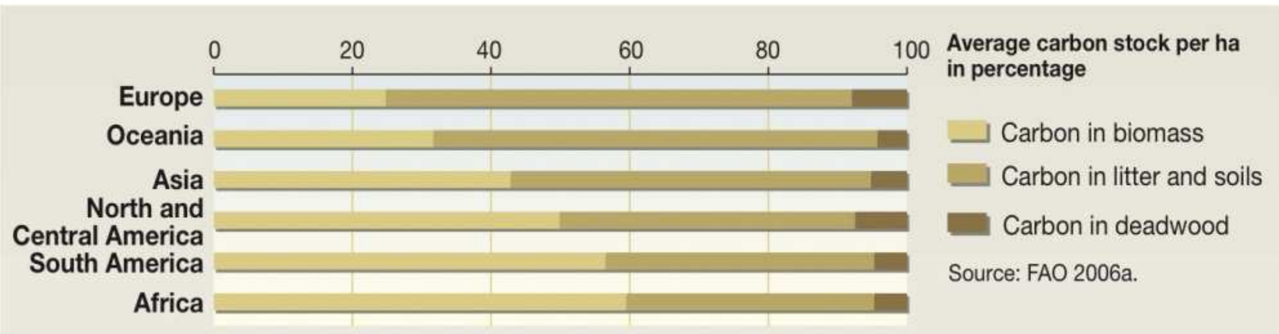

Figure 25. Average distribution of the carbon stock for different regions in the world.

The FAO estimated total carbon stocks for different regions correspond well to country characteristics on forest area. Changes may also be due to considerable changes in the compositional structure of forests, but usually such changes takes place over longer time spans and do not show in short term (10-20 years) statistical reviews.

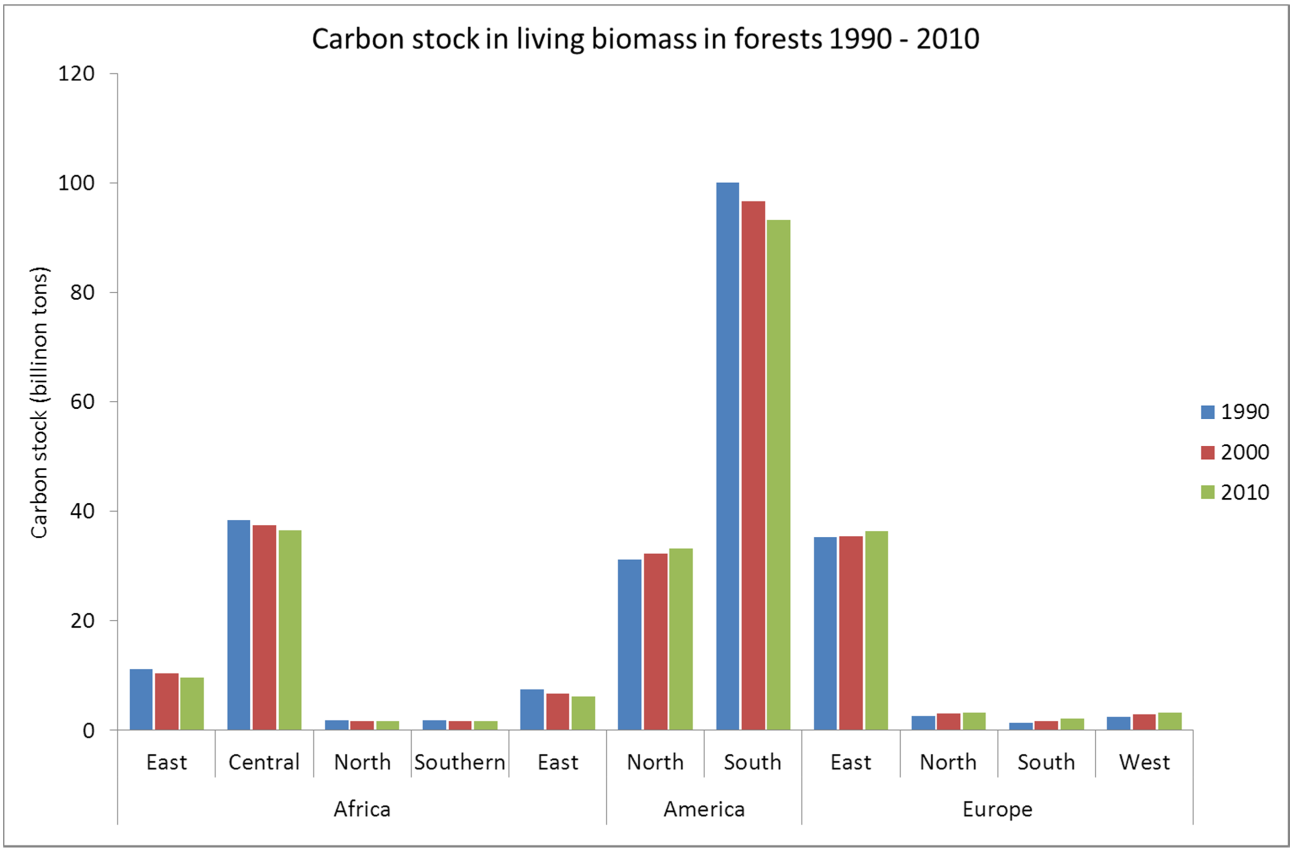

Figure 26. Carbon stored in living forest biomass in selected regions in1990, 2000 and 2010 (FAO 2010) (1 billion tons=1Gton).

8.2.2. Dynamics of forest carbon pools

The different forest carbon pools differ with regard to their dynamics. Usually three ecosystem carbon pools are considered: living biomass, deadwood and litter, and soil carbon (IPCC 2006).

Carbon stores in the soil pool are considered to be more stable and have slow dynamics (Liski, Perruchoud et al. 2002), compared to the carbon stores in the living biomass, but also with longer restoration times, if once disturbed. Some of the soil organic matter persists for millennia (Schmidt, Torn et al. 2011). Factors that may lead to decomposition and release of soil carbon include for example soil preparation and drainage (Sulman, Desai et al. 2013, Wiesmeier, Prietzel et al. 2013). In a longer term perspective, practices leading to a reduced yearly input of carbon, such as declining growth and intensified harvesting of the biomass, may also lead to decreased soil carbon pools (Liski, Perruchoud et al. 2002).

Factors that increase the input of soil organic matter, e.g. via litterfall, or decrease the decomposition of the soil organic matter can lead to accumulation of carbon in the soil. Fertilization, which increases growth, may for example increase the inputs of litter to the soil, while ceasing of drainage will usually slow down the decomposition rate. Soil sequestration rates in Swedish forest soils have been evaluated to be 40-410 kg ha^{-1} yr^{-1}, -60-360 kg ha^{-1} yr^{-1}, or -20-730 kg ha^{-1} yr^{-1}, depending on the estimation method (Berg, Gundersen et al. 2007), while Lal (Lal 2008) reports rates from the southeast of the U.S.A. to be 1.2-6 kg ha^{-1} yr^{-1}, and in Canada 12-17 kg ha^{-1} yr^{-1}.

Even if the carbon sequestered in living biomass is, on average, shorter lived than soil carbon it may remain stored for centuries. The expected lifetime of the trees is much influenced by the species, the site conditions, the natural disturbance patterns, and in the case of managed forests, also the management. The carbon in living biomass is sequestered at faster rates than in the soil. In Danish experiments biomass accumulation rates up to 14-16 tons of dry matter ha^{-1} yr^{-1} in aboveground biomass for conifers and 4-8 tons of dry matter ha^{-1} yr^{-1} for broadleaves have been achieved (unpublished data not covering a full rotation). This corresponds to an accumulation of approximately 7-8 and 2-4 tons of C ha^{-1} yr^{-1} (Graudal, Nielsen et al. 2013). Clonal eucalypt plantations in Brazil probably are close the limits of what wood biomass production systems can produce. Grown in very short rotations of 2 to 6 years, they have been reported to produce as much as 40-80 m^3 ha^{-1} yr^{-1}, with a mean annual increment of about 60 m^3 ha^{-1} yr^{-1}. Basic densities of vary from about 0.45 to 0.5 dry tonnes m^{-3}, which give a corresponding average biomass production of 27-30 tons ha^{-1} yr^{-1} and a carbon sequestration of 14-15 tons of C ha^{-1} yr^{-1}. At the age of 24 months, the diameter at breast height is about 7.5 cm and the stand height about 13 m (Couto, Nicholas et al. 2011).

There is scientific consensus for a general model for carbon dynamics of living biomass in managed forest stands. After planting/regeneration/establishment carbon assimilation evolves exponentially with a slow start. After a period of time net accumulation rates levels off and converges towards zero at maturity (figure 27, upper panel). Normally the soil carbon pools are relatively stable, while there may be some variation in forest floor dynamics. Carbon dynamics of managed forest stands are influenced by location, soil type, water availability, tree species, and management regimes but follow the overall pattern illustrated in Figure 27.

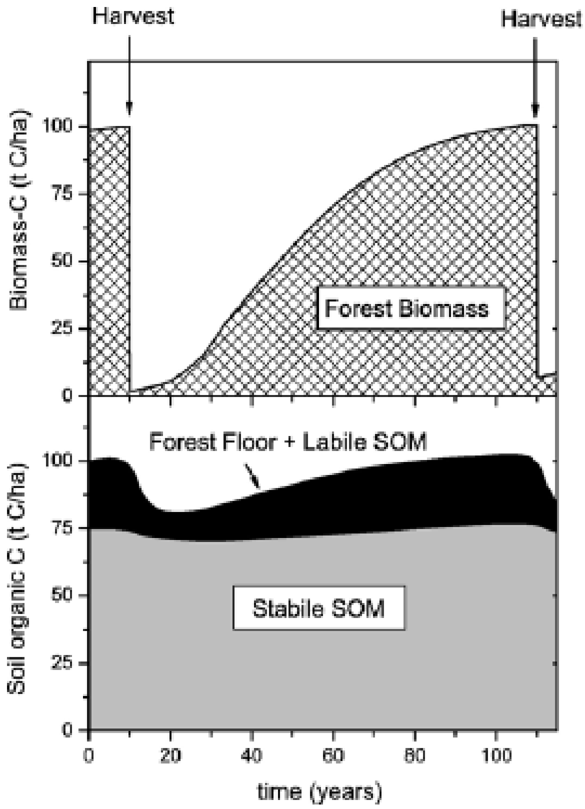

Figure 27. Conceptual illustration of carbon dynamics of managed forests. Adopted from (Jandl, Lindner et al. 2007).

More debated are the finer details on how fast new stands grow, their maximum rate of assimilation, and when and if an equilibrium is reached. Some find that unmanaged forests will reach equilibrium, where the carbon assimilation balances the net carbon release from decomposition processes in the soil, leading to zero net assimilation. Others are less inclined to believe that an upper maximum to ecosystem carbon sequestration exist. Declining growth rates with increasing tree or stand age is attributed to a shift in the ratio between photosynthetic activity (gross primary production, GPP) and autotrophic respiration (the plants own respiration to build and maintain different plant tissues) leading the net primary production (NPP) to converge towards zero. Other factors mentioned are reduced photosynthetic efficiency or reduced area of the productive apparatus (green leaves) with increasing age. Finally factors not relating to the physiology of plants, influencing the carbon balance of a forest could be increased mortality in older forests leading to increased heterotrophic respiration (Framstad, Wit et al. 2013). Based on national forest inventories (Luyssaert, Schulze et al. 2008) for example found that even century old forests could act as carbon sinks. The findings are corroborated by other studies using different methods e.g. (D'Amato, Bradford et al. 2011) (permanent sample plots) and (Knohl, Schulze et al. 2003) (detailed carbon flux measurements, so-called eddy covariance studies). Opposing observations are reported by (Lippke, Oneil et al. 2011) from the Douglas Fir region of USA. Here no net assimilation was found in stand older than ~100 years. (Schmid, Thurig et al. 2006) found through multiple model comparisons that in the absence of large-scale disturbances the forest biomass and soil carbon can be increased. Forests can be used as carbon sinks.

The sink period was estimated to last for a maximum of 100 years. A recent literature review on carbon dynamics in northern forests confirm the general pattern of carbon dynamics in managed forests (Fig 26), but demonstrate that most northern forests most likely continue to work as carbon sinks far beyond normal rotation age (Framstad, Wit et al. 2013).

8.2.3. Potential contribution from forest-based bioenergy to climate change mitigation

8.2.3.1. Background and basic concepts

The rationale for using biomass for energy is that it may displace fossil resources and potentially reduce the emissions of CO_2 or other greenhouse gasses to the atmosphere and in turn reduce the increased radiative forcing leading to a generally warmer climate. Bioenergy is commonly, but incorrectly, considered to be carbon neutral. Increased use of biomass for bioenergy will to some extent influence the exchange of carbon between carbon pools and greenhouse gas emissions to the atmosphere may be, temporarily or permanently, increased or reduced depending on practices and circumstances surrounding the utilization of biomass. Various components may be considered, such as the reference fuel, the reference forest development scenario (also called the baseline, Business As Usual scenario or counterfactual) and the associated differences in ecosystem carbon stores, the direct fossil emissions associated with the growing and extracting the raw material to energy conversion (European Parliament and the Council 2009), and impacts of direct and indirect land use changes (iLUC) (European Commission 2012). It is also important to be aware of the dynamics involved for both the biomass utilization scenario and the counterfactual; these cause the calculated net emissions to depend on the selected time perspective, and conclusions that might differ between e.g. 2020 and a longer time perspective.

Global scale modelling of bioenergy deployment and its climate impact often disregard CO_2 emitted during conversion of biomass to energy services (in the energy sector) (Agostini, Giuntoli et al. 2013). The omission of biogenic CO_2 emissions from the energy sector is based on guidelines for national greenhouse gas inventories under the UNFCCC and seeks to avoid double counting because changes in carbon stocks in forestry and agriculture are reported in the AFOLU (Agriculture, Forestry and Other Land Use) sector. As such harvest of biomass for energy is translated to an emission of CO_2 in the year of harvest irrespectively of when the biomass is used for energy. If all countries report inventories for the energy and AFOLU sector a fair assessment of CO_2 emissions from bioenergy deployment could be made. While Denmark report inventories for the AFOLU sector not all countries do and this may underestimate negative climate impacts of bioenergy production. In general global assessments of bioenergy build on very simplified models of biogenic carbon cycles because they are very difficult to monitor and to model in a tractable scale. Moreover causal relations between changes in carbon stocks and drivers are difficult to establish. For instance the natural decay of forest harvesting residues is not accounted for in IPCC's evaluations of bioenergy's contribution to climate stabilisation (Solomon, Qin et al. 2007), which may underestimate the positive climate effects of bioenergy.

8.2.3.2. Stabilisation scenarios

Much work has been put into developing climate models but long-term projections are still uncertain as for example climate-carbon cycle feedbacks are not well understood. In 1997, the IPCC (IPCC 1997) proposed a number of scenarios based on geophysical relations between the biospheres carbon pools. The scenarios show that in order to stabilise the CO_2 concentration in the atmosphere, anthropogenic emissions must peak sometime in the relatively near future and thereafter permanently stabilise on a level lower than the current emissions. The time of peak emissions, the amount of peak emission, and finally the permanent stabilisation level of emissions depend on the targeted concentration of CO_2 in the atmosphere. Targets allowing a higher increase in radiative forcing postpone the time, when emissions peak and raise the peak and stabilisation emissions. For example, If 450 ppm is the CO_2 concentration target, anthropogenic emissions could peak between 2010 and 2020 at approx. 7.5 GtC yr^{-1}, be reduced to approx. 3 GtC yr^{-1} in 2100 and stabilise at approx. 1 GtC yr^{-1} in 2300 ((IPCC 1997), page 15). T. M. L. Wigley (one of the lead authors of the IPCC scenarios) and co-authors, expands the stabilisations scenarios by incorporating qualitative economic considerations (Wigley, Richels et al. 1996). The general impact of this addition on emissions pathways is that the emission peaks are advanced, the peak emissions are raised, while the following declines in emissions until 2150 must be steeper. With reference to the 450 ppm target and the IPCC scenario, the Wigley-Richels-Edmonds (WRE) model (Wigley, Richels et al. 1996) also suggests peaking in 2010-2020, but at a higher peak level, close to 10 GtC yr^{-1}, followed by a sharper decline until 2100. In the fourth assessment report from IPCC (AR4) more stabilisation scenarios are evaluated (Fisher, Nakicenovic et al. 2007). These scenarios expand on the WRE modelling approach by incorporating economic considerations quantitatively using a least cost procedure for scenario development (i.e. economic optimisation). For CO_2 concentration targets below 485 ppm corresponding to an additional radiative forcing of maximum 4 W m^{-2} , emissions could peak between 2000 and 2030 followed by a decline in emissions reaching a level in 2050 85 % lower than the emission in 2000((Fisher, Nakicenovic et al. 2007), page 198). Correspondingly Rogelj et al. (Rogelj, Hare et al. 2011) find that CO2 emissions should peak between 2010 and 2020 and not exceed 44 Gtons CO_2 equivalents in 2020 if a target of a maximum 2^o C degree increase in average global temperature (the Copenhagen Accord) should be met[2].

The most restrictive emission pathways included in AR4 are based on a relatively narrow set of models and scenarios (van Vuuren and Riahi 2011). A recent update on emission pathways include considerably more scenarios than AR4 (129 vs. 45), and find a greater flexibility in the trade-off between short term emissions and long-term concentration targets (van Vuuren and Riahi 2011). They conclude that emissions peaking between 2020 and 2030 would still be consistent with a target of a long-term 2^o C average temperature increase.

Flexibility in short term emissions is also demonstrated in a more recent study by Rogelj et al. (Rogelj, McCollum et al. 2013). They find that GHG emissions in 2020 in the range of 41-55 Gtons of CO_2 equivalents is consistent with limiting global warming to 2^o C. However, higher emissions put pressure on future technological development and reduce flexibility if critical technologies are not developed. A 2020 emission target of 41-47 Gtons of CO_2 equivalents is recommended to reduce risks of not meeting the 2^o C target.

A number of studies find that cumulative carbon emissions provide better policy guidance than the time specific emission pathways reviewed above. This method, also reported by the IPCC, operates with 'allowable' cumulative CO_2 emissions, For example Solomon et al. suggest a maximum cumulative emission

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[2] Note that carbon emissions can be converted from C to CO_2 emissions by multiplying by 3.67. Emissions of CO_2 equivalents (CO_2 eq) cover emissions of a number of compounds other than CO_2 as CH_4, N_2O, CFC and HCFC gases and cannot directly be converted to an amount of carbon.

of 490 [confidence limits 375-600] GtC in during 21st century will ensure a concentration stabilisation around 450 ppm ((Solomon, Qin et al. 2007), page 79). Bowerman et al. (Bowerman, Frame et al. 2011) demonstrate a strong correlation between cumulative emissions since 1750 and peak CO_2 induced warming, which is seen as an indication of the method's applicability. A maximum 2^{o} C warming can be ensured by limiting cumulative emissions to approx. 1000 GtC corresponding to 3670 Gtons CO_2 counted from 1750. In the same study specific emissions in (2020 or 2050, the peak year or peak emission showed considerably poorer correlations with peak warming (Bowerman, Frame et al. 2011). Other studies from the same modelling group corroborate those findings (Allen, Frame et al. 2009, Meinshausen, Meinshausen et al. 2009). A limitation to the interpretation of the results is that they assume that climate forcing from non-CO_2 emissions is negligible, which may be the case currently, but probably not in the future (Allen, Frame et al. 2009). Meinshausen et al. (Meinshausen, Meinshausen et al. 2009) find that non-CO_2 emissions reduce the allowable amount of cumulative CO_2 emission for 2000-2050 from 400-500 GtC to just under 400 GtC. Along the same line of thinking Steinacher et al. (Steinacher, Joos et al. 2013) report that targeting more climate issues than global warming, e.g. sea level rise, soil carbon losses and surface waters may further reduce the 'allowable' cumulative CO_2 emissions. However, the method as such may still be more useful for policy guidance than time-specific methods as these limitations concern time-specific emission pathways as well.

For the 5th assessment report (AR5), to be published in 2014, working group I of IPCC has developed a set of four new storylines on future global climate change, the so-called Representative Concentration Pathways (RCPs) (Alexander, Allen et al. 2013). The RCPs are meant to form the basis of further analyses and scenario development for AR5, and are not to be seen as complete forecasts of future climate change and climate policy implications. The RCPs are not policy prescriptive. The four RCPs developed describe the expected increase in radiative forcing by 2100 relative to year 1750 at 2.6, 4.5, 6.0 and 8.5 Wm^{-2} respectively, and the associated temperature increases relative to 1986-2005 at 1^{o} C [0.3-1.7], 1.8^{o} C [1.1-2.6], 2.2^{o} C [1.4-3.1], 3.7^{o} C [2.6-4.8] respectively caused by anthropogenic emissions of CO_2 (Confidence limits in brackets). RCP2.6 is an overshoot scenario where radiative forcing peaks before 2050 and declines to 2.6 Wm^{-2} by 2100. RCP4.5 and 6 are stabilisation scenarios assuming that radiative forcing is stabilised around 2100. In the RCP8.5 radiative forcing is expected to increase well beyond 2100 and peak around 2200 at approx. 12 Wm^{-2} (van Vuuren, Edmonds et al. 2011). The difference between the SRES scenarios (Special Report on Emission Scenarios) used in IPCC's third and fourth assessment report and the RCP's is that SRES specified socio-economic boundaries for each scenario making socio-economic variables inflexible and emissions and climate change flexible. The RCP's approach the climate problem from the other side by fixing GHG emissions and subsequent global warming trajectories, and leaving socio-economic variables flexible. In this way the RCP's to a larger degree allow the efficiency of climate policies and measures to be tested against a reference trajectory of climate change.

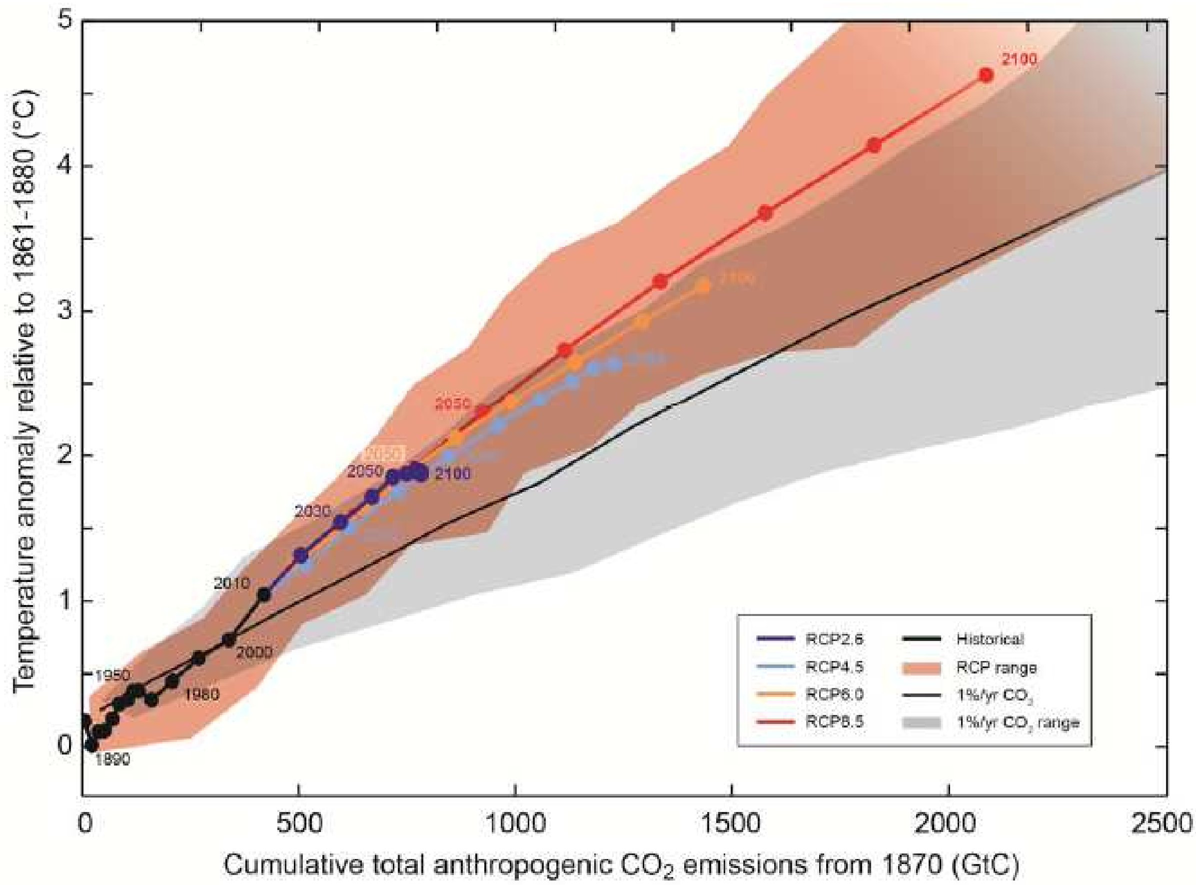


Figure 28. Relation between cumulative anthropogenic CO2 emissions and global average surface temperature increase by 2100. Figure SPM 10 from (Alexander, Allen et al. 2013).

Currently (October 2013) only a summary for policy makers can be referenced (Alexander, Allen et al. 2013). Alexander et al. find an almost linear correlation between the cumulative CO_2 emission to the atmosphere and the global mean surface temperature response by 2100 (Figure 28). Alexander, Allen et al. (2013) report that the cumulative anthropogenic CO_2 emission from 1750 to 2011 is estimated to 545 [460-630] GtC. Cumulative emissions for 2012 to 2100 compatible with the peak and decline or stabilisation RCP's, are 140-410 GtC for RCP2.6, 595-1005 GtC for RCP4.5 and 840-1250 GtC for RCP6.0.

8.2.3.3. Timing issues

The most beneficial timing of peak emissions is much debated. Using a simple conceptual model (Vaughan, Lenton et al. 2009) analyse the trade-offs between delayed action in mitigating CO_2 emissions and the required strength of mitigation measures needed to meet specific CO_2 concentration targets. They find that e.g. delaying peak emissions from 2020 to 2040 would require a subsequent reduction in CO_2 emission of 4.46 % annually instead of 1.85 % annually to meet the same stabilisation target of 500 ppm.

Stocker (2013) report similar findings with even more severe conclusions. If global CO_2 emission mitigation commences in 2040 the required emission reduction must be 5-10% annually. Stocker finds that a 'point of no return' is crossed for meeting the 2^o C target if global mitigation actions are taken later than 2044. The model used by Stocker is conceptually different than most other reported models as it assumes an exponential increase in annual emissions followed directly by an exponential decrease. Other studies referenced here assume an exponential increase followed by a more stable transition period of varying length followed by an exponential decrease. The characteristics of the model used by Stocker will inherently result in tighter timing constraints compared to models used by other scientists, but other factors may also have influenced the results.

Friedlingstein et al. (Friedlingstein, Solomon et al. 2011) also report that delayed action requires stronger action to stabilise CO_2 concentrations. With a delay of mitigation action of 30 years from now (2010) a 2^o C target can still be reached, but requires an annual decrease in emissions of 5 %. Correspondingly if action isn't delayed the same target can be reached with a 1 % annual decrease in emissions.

8.2.3.4. Emission floors

Another issue debated in the scientific literature, is the final stabilisation level of CO_2 emissions required to meet specific concentration targets, also termed the emission floor. From a geophysical point of view, the net CO_2 emissions from land use and land use change, volcanic activity and fossil resource use must be counterbalanced by ocean uptake and deep sea deposition to ensure a long term stable CO_2 concentration in the atmosphere. Even if anthropogenic CO_2 emissions are terminated instantaneously, the globe would still experience long-term warming of $0.5\text{-}1^O$ C above pre-industrial times due to inertia in the earth system (Friedlingstein, Solomon et al. 2011). Friedlingstein et al. find that a 90 % reduction in CO_2 emissions (corresponding to the higher end of range of IPCC stabilisation scenario I and lower end of range of scenario II (IPCC 2007)) would still result in increasing CO_2 concentrations in the atmosphere throughout this millennia (Friedlingstein, Solomon et al. 2011). Bowerman et al. (Bowerman, Frame et al. 2011) reach similar conclusions, that, with an emission floor at app. 1 GtC yr^{-1} long-term stabilisation of global warming below 2^o C is not likely. The 2^o C target can be reached even with continued CO2 emissions, but only if they are considerably lower than 1 GtC yr^{-1}. Bowerman et al. also caution that such results are very sensitive to model specific artefacts.

The idea of 'allowable' cumulative emissions does not contradict stabilisation scenarios based on specific emission pathways, but if the cumulative emission approach is accepted, it offers a broader space of possible solutions to limiting CO_2 induced global warming. The general characteristics of all stabilisation scenarios, time specific as well as cumulative, are that GHG emissions must peak in the near future (0-30 years) and stabilise considerably below 1 GtC yr^{-1}. Delaying the emission peak requires subsequent implementation of stronger reduction measures. Meeting the most restrictive warming targets (IPCC group I and II with concentration levels below 440 ppm) may even require negative emissions ((Fisher, Nakicenovic et al. 2007), page 199) achievable through combinations of bioenergy and carbon capture and storage (CCS) (Peters, Andrew et al. 2013) or temporarily through increased storage in biomass or biomass based stable carbon components (biochar). CCS through wood burial under anaerobic conditions has also been suggested as a means of mitigating global warming induced by CO_2 emissions (Zeng 2008).

Climate change mitigation scenarios for IPCC's 5th assessment report are still under development and are expected to be published in April 2014 (http://www.ipcc.ch/). These scenarios may change the picture of possible future actions and pathways to mitigate climate change. However, since the assessment report from working group I (Alexander, Allen et al. 2013) to a large extent confirmed earlier assessments as regards the physical science behind climate change, significant changes in the actions required to curb climate change are not expected.

8.2.4. Modelling of forest based bioenergy and its possible contribution to climate change mitigation

The greenhouse gas benefits of using forest biomass for energy instead fossil fuels are being much debated and there are divergent results and opinions. The differences in results and views partly seem to stem from differences in the scale, assumptions and system boundaries that are being applied. There are at least four parameters for which different approaches are taken e.g. (Lippke, Oneil et al. 2011, Berndes, Ahlgren et al. 2012, Lamers and Junginger 2013).

1. Spatial scale, stand level versus landscape level and underlying model assumptions
2. Temporal scale, short-term versus long-term
3. Carbon debt payback versus carbon parity point
4. The trade-off with other sustainability criteria

8.2.4.1. Spatial scale

Different spatial scales are being applied, from one tree/one stand to landscape levels. When only one tree or one stand is being considered, managed in a clear-cutting system, there is a tremendous drop in carbon stores when the stand is harvested, and until the same stand again has sequestered the amounts of carbon originally stored in the harvested biomass.

When a landscape level approach is being applied, there is usually no or only a minor drop in the amounts of carbon stored in the system, assuming there is an even distribution of stands of different ages. To ensure constant production and a stable currency flow forest management generally targets a forest area that includes stands of all age-classes (a so-called normal forest), . Assume that the forest has for example 100 stands, that are 0, 1, 2,….100 years old, that the forest is being managed with clear-cutting system, and that the stands are clear-cut when they reach the age of 100 years. Seen at this spatial scale, there will always be one stand of each age, with no overall changes in the total forest carbon stores over time (Berndes, Ahlgren et al. 2012). This is an ideal example, while under more lifelike circumstances, changes in carbon stores may also occur at the landscape level. This includes situations where there is an uneven age-class distribution (as is to some extent the case for Danish forests as a whole), or if the management is changed to more intensive harvesting regimes that generally lower the amount of carbon stored in living biomass. In the latter case, it is likely that there will be a permanent reduction of the carbon reservoir in living biomass (Fritsche, Iriarte et al. 2012, Gylling, Jørgensen et al. 2012, Graudal, Nielsen et al. 2013). After some time, however, the system is likely to reach a new equilibrium at the lower level, where there is no longer a net release of the forest carbon stores. Little is known about the extent of the reversibility in the long-term carbon stores, but again, it is very likely that the average level of stored carbon will increase again, if the management is changed to less intensive management regimes.

However, the dynamics might also be different if behavioural aspects are included in carbon debt analyses. (Sedjo and Tian 2012) argue that forest owners will react to market signals, e.g. an increase demand for forest bioenergy, and will adapt their forests management to the changed demands. In the case of increased demands for forest bioenergy this could result in more intensively managed forest, with increased stocking in existing forests and more afforestation, and consequently more carbon stored in living biomass.

Underlying model assumptions relating to spatial scale influence the outcome of studies. Stand scale models are often based on a simplified carbon flux model, such as the model used by (Cherubini, Peters et al. 2011), (Figure 29). The model represents a forest stand in equilibrium (no net carbon assimilation/emission takes place), which is clear-cut, and then left to regenerate. After another rotation period the forest reaches the initial carbon stock before being clear-cut again. These carbon flow assumptions could be representative for the exploitation of hitherto unused climax forest with no restrictions on e.g. number of trees that must be left standing after harvest. Some stand scale models also include a number of thinnings during the rotation period, between stand establishment and the next clear-cut (Eliasson, Svensson et al. 2013), but the overall pattern is similar.

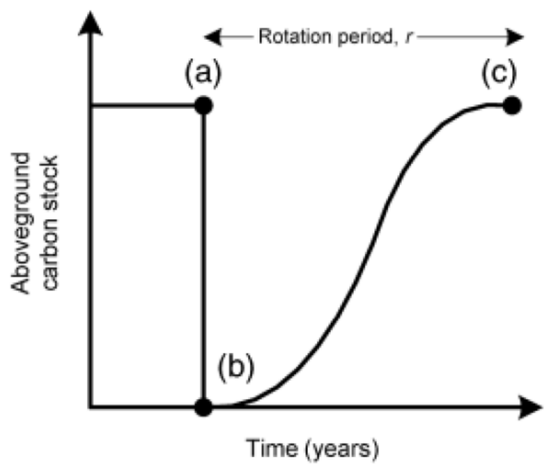


Figure 29. Simplified carbon flux model on stand scale.
From (Cherubini, Peters et al. 2011).

Landscape scale models can be made up of sequences of identical stand scale models displaced in time (Berndes, Ahlgren et al. 2012, Eliasson, Svensson et al. 2013). They can also be based on the actual composition of a forested landscape in terms of ages and species (McKechnie, Colombo et al. 2010, Hudiburg, Law et al. 2011, Ter-Mikaelian, McKechnie et al. 2011, Graudal, Nielsen et al. 2013). The size of a 'landscape' can vary substantially, from a forest management unit to the forests of an entire country. Landscape scale models may be as hypothetical as stand scale models (Lamers and Junginger 2013), but they are potentially better suited to represent a forested landscape already under management and with a specific composition in terms of species and age classes, and with a dynamic development over time. Most of the European and large parts of the North American forest area are such managed forests.

Interpretation and comparison of results on carbon debt across studies applying different scales is challenging and should be done with care as the different modelling approaches provide answers to different questions.

8.2.4.2. Temporal scale

In evaluating biomass products from production systems with short rotation e.g. annual and perennial agricultural crops, the temporal scale usually is not an issue because the temporal difference between sequestration, emission and re-sequestration of carbon is short. Furthermore such systems usually do not store large amounts of carbon in living and dead biomass. With increasing rotation ages, from annual crops over short rotation coppice (SRC) and short rotation forestry (SRF), plantation forestry, forestry in tropical, temperate and boreal biomes the temporal dimension becomes increasingly important as the time required for an ecosystem to recover or settle at a new equilibrium after disturbance (natural as well as anthropogenic) and the amounts of carbon stored in living and dead biomass increases. As carbon dynamics of ecosystems are highly time-dependent and non-linear, an inappropriate choice of temporal scale may lead to biased results. The appropriate scale should, when considering uniform production systems (even aged, clear cut monocultures) include at least a full crop rotation, which in boreal biomes may span over centuries. When considering more complex production systems such as uneven aged forest landscapes with multiple species in a so-called continuous cover management regime, the temporal scale should be expanded.

Another temporal issue regards the reference year applied in the analyses. Ideally the reference year should represent the point in time, where the decision to engage in bioenergy production is taken. All studies reviewed here build on the assumption that the decision is taken at the time of harvest. Due to the long rotation periods, decision making in forestry is a complex issue. Some elements of the decisions are taken directly before harvest, but the foundation for decisions at time of harvest is decisions taken at time of planting/regeneration, for example regarding species, forest composition, stocking, management regimes etc.

The influence of the applied temporal modelling approach on resultant carbon debts and payback times is not known, as comparable studies using different starting points, to our knowledge hasn't been published. Modelling a forest bioenergy supply scenario starting at the time of planting, rather than at the time of harvesting, would result in carbon capital being built up with subsequent capital investment to displace fossil carbon emissions, rather than a carbon debt being incurred with subsequent repayment requirements. Graudal et al. (2013) demonstrate that incorporating bioenergy production already in the forest planning phase could enable the Danish forests to produce significantly more biomass for energy purposes, while simultaneously build up more carbon in living biomass. As such increased bioenergy production does not automatically conflict with the preservation of carbon in living biomass.

Starting the modelling at the time of harvesting for one or all stands is only relevant in the case, where areas of unmanaged forest are clear-cut, and even then the normal disturbance dynamics of the forest should also be taken into account. Often fires, insect pests, and windthrows are naturally occurring disturbances that lead to a reduction in living biomass and subsequent release of the stored carbon into the atmosphere as the deadwood decomposes.

There is an inherent conflict when the time horizon of short-term policy goals is applied to systems that work over longer time horizons. When focus is on achieving for example 2020 targets for reduction of greenhouse gas emissions, this may in some cases lead to conclusions that carbon emissions from forest energy are higher than, for example, emissions from oil (Repo, Tuomi et al. 2011, Repo, Känkänen et al. 2012). In 2020, the conclusion may again be that goals set for 2050 cannot be reached by use of forest biomass, using the same argument. However, when using short time scales, even in a sequence, the potential long-term benefits of forest bioenergy is lost. This conflict calls for caution when interpreting carbon debt studies for the evaluation of policy goals (Cowie, Berndes et al. 2013).

In the very long term perspective, forest energy that does not lead to a degradation of the forests productivity will inherently have benefits over fossil fuels, also when it leads to century-long temporary losses of forest carbon stores. The crucial point is that carbon stored in biomass remains on the fast carbon cycle with decade or century long turnover, while using fossils move carbon from the slow carbon cycles that work over millions of years into the fast carbon cycle.

8.2.4.3. Carbon debt or carbon parity

The terminology applied to express the so-called carbon debt is ambiguous among different studies on the sustainability of forest bioenergy. However, two fundamentally different approaches can be separated: Carbon debt repayment and carbon offset parity. According to (Mitchell, Harmon et al. 2012) carbon debt repayment or carbon debt payback time refers to the time it takes the initial change in carbon storage and new forest growth incurred because of bioenergy production to be counterbalanced by the displaced fossil carbon (Figure 30). The carbon offset parity point refers to the point in time where a bioenergy scenario not only is counterbalanced by the displaced fossil CO_2 emission, but also counterbalance the carbon sequestration that would have taken place had the biomass not been harvested for bioenergy purposes. (Mitchell, Harmon et al. 2012) applies the assumption that no harvest would have taken place, as would be the case in an un-managed and un-disturbed forest, but the carbon parity approach can be equally applied to forests under continued forest management.

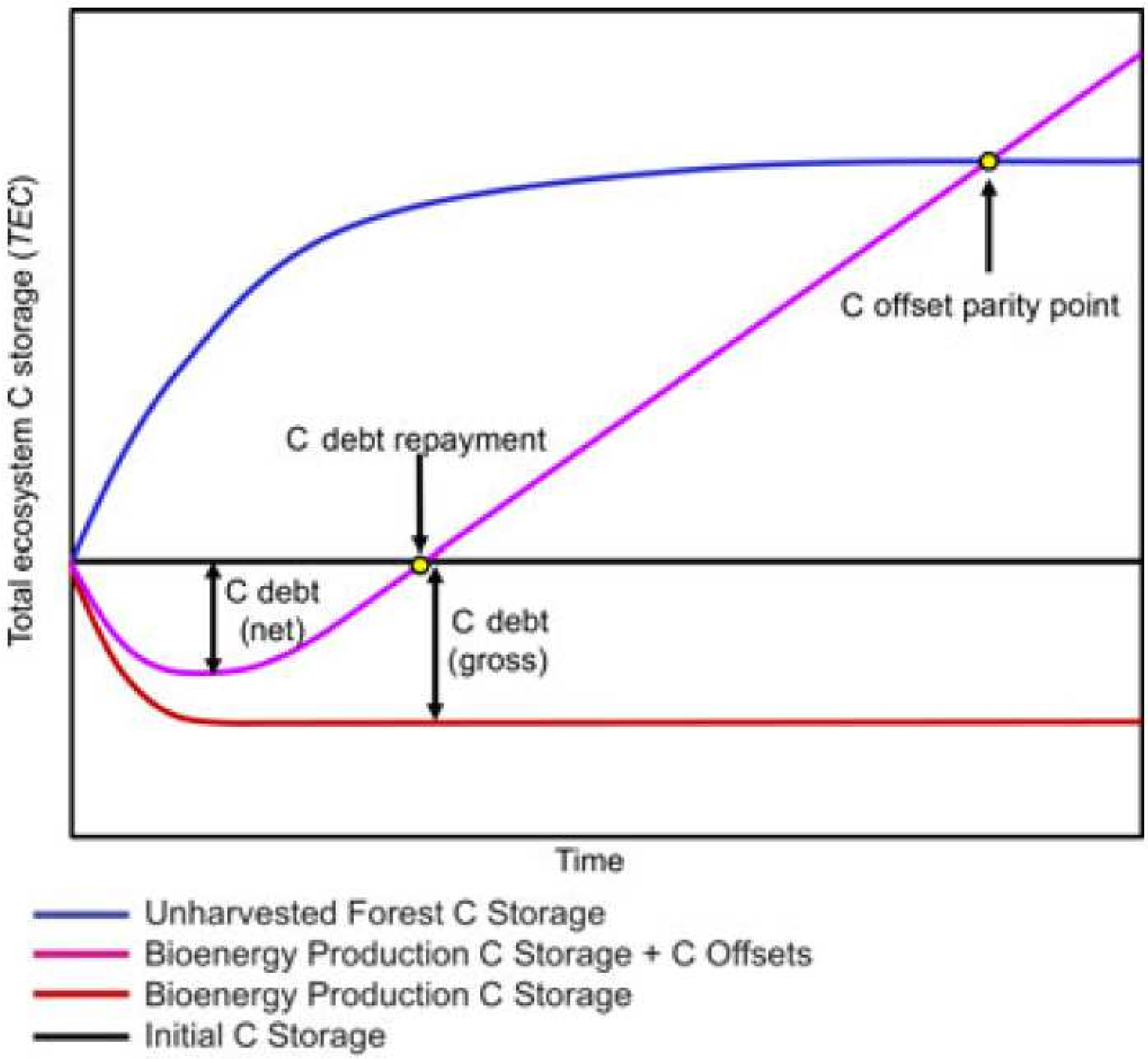


Figure 30. Conceptual illustration of the two accounting methods applied in the literature on forest bioenergy and carbon dynamics. Adopted from (Mitchell, Harmon et al. 2012), figure 1.

Characteristics and assumptions applied in a number of recent studies on forest bioenergy are listed in Table 3.

Table 3. Modelling characteristics of a number of recent forest bioenergy carbon dynamics studies.

	Scale	Data	Accounting	Biome	Forest history	Management baseline	Management scenarios	Fossil reference
Walker (2013)	Stand	Hypothetical	Payback	Temperate	Planted	Continued timber harvest	Baseline + logging residue harvest Intensified timber + logging residue harvest	Coal or gas to electricity Oil or gas to heat
Zanchi (2012)	Landscape	Hypothetical	Payback	Temperate	Unknown	Continued timber harvest	Baseline + logging residue harvest Intensified timber harvest Intensified timber + logging residue harvest	Coal, oil or gas to electricity
Repo (2011)	Landscape	Hypothetical	Payback	Boreal	Planted	Continued timber harvest	Baseline + logging residue harvest Stump harvest	Coal, oil or gas to electricity
Repo (2012)	Landscape	Hypothetical	Payback	Boreal	Planted	Continued timber harvest	Baseline + logging residue harvest Stump harvest Thinning wood harvest	Coal, oil or gas to electricity
Lamers (2013)	Stand Landscape	Hypothetical	Payback Parity	Sub-boreal	Naturally regenerated MPB affected forests	Continued timber harvest Protection	Baseline + logging residue harvest Intensified timber harvest	Coal to electricity
McKechnie (2011)	Landscape	Inventory, spatially explicit	Payback	Temperate	Naturally regenerated and planting	Continued timber harvest	Baseline + logging residue harvest Intensified timber harvest	Coal to electricity Oil to liquids
Jonker (2012)	Stand Landscape	Hypothetical	Payback Parity	Temperate	Planted	Protection Natural regeneration and thereafter protection	Intensified timber harvest	Coal to electricity
Ter-Mikaelian (2011)	Landscape	Inventory, spatially explicit	Payback Parity	Boreal	Naturally regenerated Planting	Protection	Intensified timber harvest	Coal to electricity
Bernier (2013)	Landscape	Hypothetical	Payback	Boreal	Naturally regenerated	Protection	Intensified timber harvest	Oil to heat
Holtsmark (2012)	Landscape	Hypothetical	Parity	Boreal	Naturally regenerated	Continued timber harvest	Intensified timber harvest	Coal to power Oil to liquids
MANOMET (2012)	Stand	Hypothetical	Payback	Temperate	Planted	Continued timber harvest	Baseline + logging residue harvest Intensified timber +	Coal or gas to electricity Oil or gas to

							logging residue harvest	heat
Colnes (2012)	Landscape	Inventory, spatially explicit	Payback	Temperate	Planted	Continued timber harvest	Intensified timber + logging residue harvest	Coal or gas to electricity Coal to CHP
Mitchel (2012)	Landscape	Hypothetical	Payback Parity	Temperate	Afforestation Recently disturbed Old-growth forest Harvested forest	Protection	Intensified timber harvest	Various

Across the scientific literature on carbon payback and carbon parity offset times of forest biomass used for energy there is considerable variation in estimates of either the carbon payback time or the carbon parity offset time (Figure 31). Apart from spatial scale, as described above, the biome and the climate regime of the location from which the biomass origins, the type of biomass (residue or stem wood) as well as the fossil fuel that biomass is displacing will influence the results. Recently a number of reviews of carbon debt studies have been published covering almost the same body of literature (Fritsche, Iriarte et al. 2012, Agostini, Giuntoli et al. 2013, Lamers and Junginger 2013).

Table 2. Carbon parity times for different biomass types by biome and reference case.

Biomass type	Biome: reference case	Min	Max	Studies: forest management regime
Residues/ Slash[a]	(Sub-) Boreal: BAU + coal based electricity	0	16	[23,24,30,33,53]: collection instead of slash-burn or decay
	(Sub-) Boreal: BAU + oil based electricity	3	24	[23,24,53]: collection instead of decay
	(Sub-) Boreal: BAU + natural gas based electricity	4	44	[23,24,53]: collection instead of decay
(low-grade) Roundwood[b]	Temperate southern: Protection[c] + coal electricity	12	46	[29]: thinnings and additional fellings on existing plantations (20-25 year rotation)
	Temperate southern: BAU + fossil electricity mix	35	50	[61]: thinnings and additional fellings on existing plantations (35 year rotation)
	(Sub-) Boreal: Protection + coal electricity	0	105	[25,30,33]: additional fellings in previously unmanaged forest
	(Sub-) Boreal: Protection + oil heating	90		[18]: additional fellings in previously unmanaged forest
	(Sub-) Boreal: BAU + coal electricity	53	230	[21,30,53]: additional fellings in previously un-/managed forest
	(Sub-) Boreal: BAU + coal electricity	17	114	[53]: clear-cut replaced with SRC[d] (10-20 year rotation)
	(Sub-) Boreal: BAU + oil electricity	20	145	[53]: clear-cut replaced with SRC[d] (10-20 year rotation)
	(Sub-) Boreal: BAU + natural gas electricity	25	197	[53]: clear-cut replaced with SRC[d] (10-20 year rotation)
	(Sub-) Boreal: BAU + natural gas electricity	300	400	[53]: additional fellings in managed forests
	(Sub-) Boreal: BAU + fossil electricity	0	0	[53]: afforestation

Applied definitions:
[a]Slash: residues from timber harvesting including tops and branches (possibly also stumps in the case of Finland and parts of Sweden) of harvested/merchantable trees, whole non-merchantable trees (e.g. standing, cracked deadwood).
[b] Dedicated removal/harvest of round-/stemwood for energy will foremost target low-grade timber fractions (e.g. pulpwood). It is highly unlikely that sawlog quality stemwood systematically ends up as bioenergy feedstock. Low-grade timber harvest typically includes operations such as:
Thinnings: pre-/commercial cutting of selected rows/individual trees to allow a stronger growth of remaining trees.
Additional fellings: increased harvesting intensity in a defined region i.e. higher biomass outtake than under a BAU scenario (i.e. timber harvest).
[c]'Protection' equals no harvest.
[d]SRC: Short rotation coppice (dedicated energy plantation) with a high (10 year) and low (20 year) productivity .

Figure 31. Overview of carbon parity studies from (Lamers and Junginger 2013). Studies referred to are ref 18: (Bernier and Paré 2012), 21: (Holtsmark 2012), 23:(Repo, Känkänen et al. 2012) , 24:(Repo, Tuomi et al. 2011), 25: (Ter-Mikaelian, McKechnie et al. 2011), 30: (Lamers, Junginger et al. 2013), 33: (McKechnie, Colombo et al. 2010), 53: (Zanchi, Pena et al. 2012), 61: (Colnes, Doshi et al. 2012).

The results indicate a tendency of biomass from the boreal biome having a longer parity offset time than biomass from the temperate zone. Residues tend to have a shorter payback/parity offset time than stem wood (see also (Fritsche, Iriarte et al. 2012)) and if wood is used to displace coal for power production the payback/parity offset time is shorter than for biomass displacing e.g. gas for power production or petroleum for gasoline production.

8.2.4.4. Conclusions on the interpretation of forest carbon dynamics studies

Evaluations of the potential role of forest biomass in the energy supply must build on both carbon dynamics of forest bioenergy supply system and the energy supply system being displaced in the context of a particular climate stabilisation scenario.

Berndes et al. (Berndes, Bird et al. 2011) argue that under the assumption of an 'allowable' CO_2 emission space, short term emissions from forest bioenergy deployment could be accepted in order to push the development of the energy system towards more renewable energy. The path to a new stabilisation level is indifferent to temporary fluctuations in CO_2 emissions as long as it doesn't cross the limit of the allowable cumulative emission.

The opposite argument is seen in the work of e.g. the Danish think tank Concito (Concito 2011, Concito 2013). Their recommendations build on a focus on the risks of surpassing climatic tipping points instigating critical bifurcations (points of no or very difficult return) in the global climate system (Rockstrom, Steffen et al. 2009, Scheffer, Bascompte et al. 2009, Lenton 2011). These concerns particularly relate to so-called overshoot climate scenarios, where peak global warming is higher than the long term equilibrium temperature as reported by e.g. (Vaughan, Lenton et al. 2009) and (Friedlingstein, Solomon et al. 2011). Following this line of reasoning the path to a future equilibrium is not indifferent if the risk of crossing critical boundaries is sufficiently high. Thus, an acceptable development including bioenergy in the energy mix relies on a very short carbon payback time, or management systems that do not, directly or indirectly, reduce the amount of carbon stored in living or dead biomass, or in the soil.

Weighing the risk of crossing climatic tipping points against the risk of long-term climate warming is speculative. The empirical evidence of CO_2 induced global warming is abundant (Alexander, Allen et al. 2013), whereas the same is not the case for climatic tipping points. On the other hand the consequences of crossing tipping points may be more severe than gradual warming up to a certain level. Dehue (Dehue 2013) argues that the risk of instigating carbon debts through the use of forest biomass is highly asymmetrical because the carbon debt of bioenergy is or can be reversible in contrast to continuous fossil emissions, which to a much higher degree are irreversible. Using fossil energy carriers with lower initial GHG emissions compared to forest bioenergy is only recommendable under assumptions that sustainably produced biomass is not available, that the scaling up itself threatens sustainability, that further development of existing renewable technologies, or development of new technologies will be able to replace fossil resources adequately and sequester the carbon emitted due to delayed action on transforming the energy supply to renewable sources.

Where the carbon debt/parity offset plays a significant role in forest bioenergy studies the issues has not yet been included in energy system analyses on the potential role of biomass and bioenergy in a future non-fossil energy system. The Danish 'Klimakommissionen' (Danish Commission on Climate Change Policy 2010) and the CEESA project (Lund, Hvelplund et al. 2011) do not emphasizes carbon payback times, but focus on bioenergy's qualities and its use in sectors, where no alternatives are foreseen for air, sea and heavy road transport as well as in power system regulation.

At the current state of development carbon debt or carbon parity offset studies appear to be very sensitive to the modelling approach and the assumptions with the reproducibility consequently being low. Although dealing with longer timespans, in some cases centuries, they often do not include the development in reference technologies, energy system configurations, or the future composition of the energy demand. Finally, such studies consider only one aspect of sustainability, the global warming potential, while disregarding other sustainability aspects described in this report.

8.2.5. Trade-off with other sustainability criteria

In the controversies around greenhouse gas benefits of forest-based bioenergy, it should not be overseen that there are other sustainability issues to consider, and that there may be trade-offs with greenhouse gas benefits (Berndes, Ahlgren et al. 2012, Duncker, Raulund-Rasmussen et al. 2012). Even if short- or long-term carbon benefits can be achieved, the production of wood fuels may be unsustainable, because the impacts are in conflict with other prioritised sustainability criteria, conservation or management goals. On the other hand, prioritization of for example biodiversity may lead to a situation where the management will be less sustainable with regard to the greenhouse gas benefits that could otherwise have been obtained.

8.3. Biodiversity

The overall global threats to biodiversity was addressed already in the Brundtland report (United Nations General Assembly 1987), which concluded that many biologically rich ecosystems are severely threatened. At the World Summit in Rio 1992, the Convention on Biological Diversity (CBD) was launched, thereby providing biological diversity with a dedicated international global agreement. Its legal power is limited, and countries remain sovereign right to exploit their own natural resources, but the convention provides a framework for setting strategic goals related to the conservation of biological diversity, and for coordinating and catalysing policies and activities related to these goals (Snape III 2010) an approach to governance, which is sometimes called 'pledge and review' (Heyvaert 2013)).

In 2010, at the 10th Conference of the Parties (COP) meeting in Japan, the CBD adopted a Strategic Plan for 2011-2020 with five strategic goals being set to reduce or stop the loss of biological diversity (www.cbd.int/sp/elements/default.shtml):

- Address the underlying causes of biodiversity loss
- Reduce the direct pressures on biodiversity and promote sustainable use
- Improve the status of biodiversity
- Enhance the benefits to all from biodiversity and ecosystem services
- Enhance implementation of strategic goals

Three to six specific targets have been specified for each goal, amounting to a total of 20 targets to be reached by 201 or 2020 (the so-called Aichi Biodiversity Targets). The goals and targets provides a flexible framework for the establishment of national or regional targets, with target 17 encouraging that Parties to the convention develop and commence implementing an effective and participatory national biodiversity strategy and action plan, that incorporates the information available from the convention. The parties have committed themselves to inform the COP of the national targets and associated policy instruments, as well progress the strategy and its milestones (www.cbd.int/sp/elements/default.shtml).

In a forestry context, one of the most severe threats to biodiversity is deforestation. Deforestation rates have slowed down and the focus on conservation of biodiversity has increased, but threats are still alarming, as are threats in some temperate and boreal forest regions (European Environment Agency 2010).

In developing countries, a number of wood uses for energy may contribute to putting pressure on forests and their biodiversity values, including local subsistence use and charcoal production, and pressure by immigrants hired to work in adjacent wood energy plantations, but needing to settle in and clear natural forest remnants (Naughton-Treves, Kammen et al. 2007). A major concern is also the conversion of tropical rainforests with extensive, mono-specific plantations (e.g., palm oil in Indonesia or eucalypt in Brazil), while in developed countries, concerns are more often related to reductions in deadwood and downed woody debris and the species that are dependent on this substrate for their living (Lattimore, Smith et al. 2009).

Other mentioned concerns include shorter rotations that alter forest structure, land-use changes, increased forest access, the spread of invasive species, and the proliferation of pest species, e.g. when wood fuel raw materials are piled and left to dry in the forest.

Lattimore, Smith et al. (2009) summarizes that the effects of forest management operations on biological diversity can occur at a number of levels, including landscapes, ecosystems, habitats, species, and genes. They list the following potential biodiversity impacts of forest practices related to wood fuel production and harvesting:

- Habitat loss or gain due to landscape and ecosystem changes;
- Removal of niche habitats (i.e., dead and downed wood);
- Disturbances to wildlife from increased forest access;
- Encroachment into protected areas;
- Proliferation of invasive species;
- Overall changes in ecosystem health.
- Impacts on forest regeneration

Considering that forest management usually aims a number of goals, many of the mentioned impacts are risks associated with forest management generally, while other are especially related to wood fuel production and harvesting.

Jonsell (2008) reviewed the impacts of wood fuel harvesting practices on biodiversity, focusing on the impacts of the increased removal of deadwood that result from current practices in the boreal region of Fennoscandia. Generally, only few biodiversity values are associated with coniferous residues removed for energy in these countries. However, he mentions that it is important retain broadleaved deadwood and wood in more progressed stages of decay in these regions, and also that precaution should be taken in areas, where deadwood supports a rich fauna or flora. He recognises, however, that the challenge how to define such areas persists.

Riffell, Verschuyl et al. (2011) reviewed the effects on biodiversity of removing deadwood in the forests of the U.S.A. They concluded at least a short-term decrease in the number of birds have been observed after extensive removal of harvest residues. They analysis also suggested that a decreased biomass of invertebrates may occur, even if they did not find evidence for an effect on the diversity or abundance of taxonomic groups. They found little evidence for large or consistent responses of other fauna to course woody debris and snag manipulations.

Riffell, Verschuyl et al. (2011) also discuss that intensified harvesting with increased deadwood removal will not take place everywhere nor at the same time in those places, where it is practiced. It is thus very likely, that dead wood resources, including snags, downed course woody debris and fine woody debris, will be abundant in other parts of the landscape. Another point is that removals are rarely as comprehensive in practice as they are under experimental conditions.

Finally, Lattimore, Smith et al. (2009) also mention that wood fuel production systems also have the potential to increase biodiversity. For example, afforestation of former agricultural lands may create new habitat for some species, while thinning or replacement of degraded stands can improve forest structure for other species.

It is a complex issue to describe and measure biodiversity, and it is a challenge to find a balance between indicators that are effective, but still economically and practically feasible. The approach is often to use high-level indicators, such as the amount of forest designated to biodiversity conservation, but some of them are also more closely related to the population processes and species, for example the amount of deadwood. In an analysis of forest policies globally, (McDermott, Cashore et al. 2012) note that it is a topic that deserves special attention, but that it is not easy to deal with from a policy perspective. They choose to focus on the extent of the protected area and the extent of species and habitats at risk, as there is some scientific evidence that these measures do support the intended goals. The information available to monitor more specific indicators, for example those aiming at protection of species and habitats within managed forests, is usually less comprehensive compared to more aggregated indicators, addressing whole forest areas of a specific type (FOREST EUROPE, UNECE et al. 2011).

To protect biodiversity, (Fritsche, Iriarte et al. 2012) suggest that an approach where forests with a high level of biological diversity are defined and that such areas be exempted from extraction of forestry products such as timber and bioenergy. Primary and old-growth forests are as such suggested to be exempt from extraction of forest products, unless the extraction is compatible with biodiversity conservation. For other forest they suggest that maximum extraction rates be set for residues and other decaying live or deadwood. The introduction of for example primary forest as a no-go area for obtaining biofuel raw materials is much discussed, see e.g. (IEA Bioenergy 2013) and (Pesklevits, Duinker et al. 2011).

As touched upon by Jonsell (2008) the challenge will be to define areas with faunal and floral biodiversity values that will be harmed by residue extraction and other bioenergy related operations. Different approaches are already being used to define such areas. For example, the FSC forest certification system uses the concept High Value Conservation Forest (HVCF). Forest owners and managers are decides whether a forest has high conservation values, but they are strongly encourage to consult other users of the forest, or people with specialist knowledge (FSC/Proforest 2009). The existence of HVCF does not mean that the whole forest is turned into a conservation area or that any forest management is excluded per se, but assumes that it is a characteristic of small, low intensity and community forests (FSC 2008).

Several international frameworks also exist to protect species and habitats within a managed forest, with overall criteria, more specific indicators to be monitored, sometimes also operational guidelines for the forest management to improve its performance against the defined criteria and indicators. An example of guidelines developed to address biodiversity specifically is the ITTO/IUCN guidelines for the conservation and sustainable use of biodiversity in tropical timber production forests (ITTO and IUCN 2009).

International level guidelines also include the Pan European Operational Level Guidelines (PE OLG) under FOREST EUROPE (Annex 2 to Resolution L2 from the Ministerial Conference of FOREST EUROPE/MCPFE in Lisbon in 1998). These address SFM more broadly, but with a specific set of forest management planning and best practice guidelines for "Maintenance, conservation and appropriate enhancement of biological diversity in forest ecosystems" (Criterion 4). Several regional, national and subnational guidelines also include Best Management Practices (BMPs) for biodiversity, see chapter 11. One of the main challenges in the development of such guidelines is to define which are the critical extraction levels and also at which spatial scales these should aim. The landscape level seem to show the most relevant dynamics, and thus is the most appropriate level for addressing forest biodiversity issues (Jonsell 2008).

If prescriptions are too strict, opportunities to obtain e.g. greenhouse gas benefits and support economic development in especially developing countries may unintentionally be foregone. If they are too loose, biodiversity and other values, such as soil quality and site productivity, might be at stake. Research supporting the development of biodiversity guidelines for the forest management is scarce, and this topic remains an under-researched. The complexity of such research is underlined by studies indicating an overarching importance of the land use history for the baseline level of biodiversity e.g. (Elbakidze, Angelstam et al. 2011). Studies that focus on locations with a long tradition for relatively intensive management may not capture the original biodiversity potential of these locations, even when rigorous scientific experiments with repetitions and controls are set up.

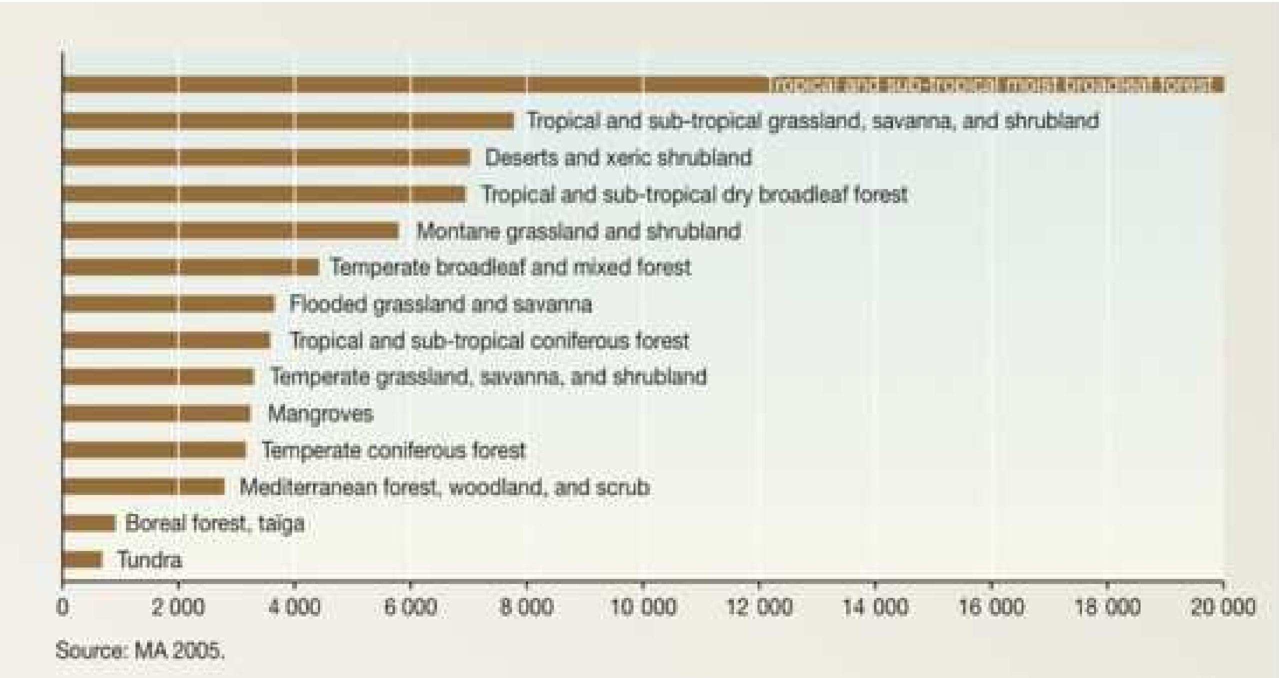


Figure 32. The number of animal species associated with different ecosystems (GRID-Arendal 2013), http://www.grida.no/graphicslib/detail/number-of-animal-species-per-biome-ecosystem_c24c Credited Philippe Rekacewicz assisted by Cecile Marin, Agnes Stienne, Guilio Frigieri, Riccardo Pravettoni, Laura Margueritte and Marion Lecoquierre.

8.4. Soil quality

Lattimore, Smith et al. (2009) summarises how soil chemical and biological properties can be altered by forest biomass production systems. They find that the impacts most often cited in the literature are:

- Reduced levels of soil organic matter (SOM) and soil carbon (C) storage;
- Changes in substrate and microclimate for soil microorganisms;
- Reduced soil nutrients; and
- Base cat-ion depletion, resulting in soil acidity.

Lattimore, Smith et al. (2009) further mention that while the effects of changes in soil chemical and biological properties on long-term site productivity are still relatively ambiguous, the effects of physical site disturbances (e.g., soil erosion, compaction and rutting) are better known. Physical soil disturbances may occur due to increased machine traffic in the forest, and less brash available for mats protecting from soil compaction due to the traffic. Changes in soil moisture and organic matter may also have indirect impacts soil physical properties. Thiffault, Hannam et al. (2011) published a meta-analysis of a large number published field studies, which reveal that soil chemical properties, including SOM and soil carbon, are often altered in response to intensified management practices.

Probably derived effects on stand productivity have been shown on some sites (Fleming, Powers et al. 2006, Helmisaari, Hanssen et al. 2011, Thiffault, Hannam et al. 2011), but impacts vary considerably from site to site, and causes of the site-specific effects are still largely unclear, even if there are indications that nitrogen deficiency is inducted in the boreal zone, where the input from the atmosphere is low, often <5 kg N ha^{-1} yr^{-1}, as compared to ranges of 10-40 kg ha^{-1} yr^{-1} in Denmark and Southern Sweden (Raulund-Rasmussen, Stupak et al. 2008).

Even if stand productivity is often used to indicate the soil's ability to support productivity, these two characteristics are not necessarily synonymous; for example, use of genetically improved stock, appropriate planting density and other site-specific reforestation techniques may result in increased tree growth compared to the previous rotation (Mead and Smith 2012). In some cases, such measures can mask detrimental soil impacts that would otherwise have led to reduced growth. While reduced tree growth is indicative of reduced site productivity, lack of apparent negative impacts on growth (or even improved growth) does not necessarily indicate a lack of negative impacts on soils and soil-related biodiversity.

Additional potential impacts may exist when direct and indirect land use changes, such as deforestation are considered. Land use changes may lead to a rapid decrease in soil quality due to soil exhaustion, with an increased need for external inputs to maintain the production (Tiessen, Cuevas et al. 1994). Erosion and even landslides may also result when a forest cover is removed.

8.5. Water quantity and quality

Wood fuel production and harvesting may affect hydrological processes and water quality (Lattimore, Smith et al. 2009). The main concerns are that groundwater and aquatic ecosystems in and around wood fuel production sites could be subject to:

- changes in water yield and peak flow,
- changes in stream temperature and light infiltration,
- increased turbidity and sedimentation,
- increased concentration of N and other nutrients, and
- accumulation of toxic substances in waters.

Neary and Koestner (2012) reviewed the effects on forest bioenergy feedstock harvesting on water in detail and conclude that water-quantity effects of forest bioenergy production are normally associated with vegetation management and related soil disturbances, while water-quality effects mostly occur as a result of soil disturbances during harvesting, the use of intra-rotation silvicultural chemicals (ash, fertilizers, and herbicides), and inter-rotation site preparation for forest regeneration. Often best management practices exist to minimize the adverse impacts of forest operations on water quantity and quality (Neary 2013).

As for soil quality, the impacts on water may also be substantial if land use changes as deforestation are involved. Deforestation leads to increased water yield in catchments (Brown, Zhang et al. 2005), while and establishment of high yielding biomass plantations on previously sparsely vegetated lands may also reduce downstream water availability (Berndes, Ahlgren et al. 2012).

A total of 329 million ha of the global forest area is currently designated to the protection of soil and water (FAO 2010), with the largest part of the located in Asia and Europe (Figure 33).

Region/subregion	Information availability		Area of forest designated for protection of soil and water	
	Number of countries reporting	% of total forest area	1 000 ha	% of forest area
Eastern and Southern Africa	23	100.0	12 627	4.7
Northern Africa	7	99.1	3 851	4.9
Western and Central Africa	24	100.0	3 079	0.9
Total Africa	**54**	**99.9**	**19 557**	**2.9**
East Asia	5	100.0	83 225	32.7
South and Southeast Asia	17	100.0	56 501	19.2
Western and Central Asia	24	100.0	13 703	31.5
Total Asia	**46**	**100.0**	**153 429**	**25.9**
Total Europe	**46**	**100.0**	**93 229**	**9.3**
Caribbean	12	53.8	1 430	38.3
Central America	7	100.0	1 718	8.8
North America*	5	100.0	0	0
Total North and Central America	**24**	**99.5**	**3 148**	**0.4**
Total Oceania*	**21**	**99.8**	**926**	**0.5**
Total South America	**14**	**100.0**	**58 879**	**6.8**
World	**205**	**99.9**	**329 168**	**8.2**

Figure 33. Area of forest designated for protection of soil and water in 2010. From (FAO 2010).

8.6. Input of chemicals

The use of chemicals such as fertilizer and pesticides in to increase or maintain bioenergy feedstock production may have adverse effects on soil, water and biodiversity, even if the inputs of chemicals to forest and wood energy production systems are generally low compared to agriculture. However, more intensive management regimes to produce additional biomass may require increased input of fertilizer and pesticides.

The use of fertilizer in agriculture is known to have significant effects on nitrate concentrations in groundwater and eutrophication of lakes and streams (van Grinsven, ten Berge et al. 2012). With dosages of 150 kg N ha^{-1}, Swedish experiences suggest that about 5% of the added fertilizer is lost to adjacent waters (Nordstedt 2001), but according to (Mead and Smith 2012), losses of fertilizer-applied nutrients in forests due to leaching and denitrification can be up to half of what is applied, even if incorporation into the soil usually dominates, also over the size of the uptake in the stand. They mention that the size of the leaching depends on the fertilizer type, humus and soil properties, vegetation present, and the size of the rainfall and consider that leaching is most likely to be larger on sandy soil, soils with low clay content, and on peat soils.

The possibilities of the stand to take up the nutrients depend on the time of fertilizer addition during stand development. Generally it is recommended to apply the fertilizer when the nutrient demand is high, with the nutrient demand increasing as a stand develops and levelling off after canopy closure (Raulund-Rasmussen, Stupak et al. 2008, Mead and Smith 2012). After crown closure nutrients are supplied from the internal cycling via the litterfal. Mead and Smith (2012) also mention that thinning can lead to an additional demand for nutrients because of the space provided for crown expansion.

The use of fertilizer in forestry usually only takes place once or few times during a long rotation period, with the impacts being temporary and small, also because of the large amounts of nitrogen already present in the ecosystem (Mead and Smith 2012). Legislation and recommendations concerning liming or the use of nitrogen fertilizer in forests may differ among countries and jurisdictions. For example, fertilization is not allowed Canadian and U.S. forests (Titus, Thiffault et al. 2012), while it is a rather common practice for example in Sweden. In the latter half of the 1970s, forest fertilization was at its highest in Sweden, with a fertilized area of nearly 200,000 hectares per year. However, from the mid-1990s, the area fertilized with nitrogen has been only about 20,000-25,000 hectares per year, mainly in northern and central Sweden. The growing interest in removal of forest biomass for energy has led to renewed interest in nitrogen fertilization, to compensate increased nutrient removals and or simply to increase growth and biomass production. The conventional dosage is 150 kg N ha^{-1}, but up to 200 kg ha^{-1} can be applied. It is recommended that there be at least 8 years between each fertilization event (Skogsstyrelsen 2007).

Pesticides are used for control of woody weeds and herbs, or for combat of pest insects, or mammals such as rabbits, grey squirrels or other rodents (FSC 2013). A survey of pesticide use in European forestry revealed significant differences between countries with little use in e.g. the Nordic countries, but significant applications of particularly insecticides or fungicides in the UK and the Czech Republic (Willoughby, Balandier et al. 2009, McCarthy, Bentsen et al. 2011). In Canada, following a government decision, the use of pesticides in forestry has been almost abolished (Thiffault and Roy 2011). Pests and diseases can cause large losses in monocultures, and it might sometimes be profitable to use expensive pesticides to combat such attacks, e.g. in oil palm or eucalypt plantations (Zhou 2012, FSC 2013), even if control and prevention of pests and diseases through organic methods can sometimes be effective, or Integrated Pest Management can often be applied as an effective measure to minimize the use of pesticides (Proforest 2003).

8.7. Air quality

Air quality is mainly an issue at the conversion plant. The emissions from biomass combustion differ from those of fossils in some regards, but also depend on the protective measure implemented at the plant. Emissions from bioenergy production can vary by feedstock, technology, and the extent to which emission controls are used, with bioenergy feedstocks such as wood and wood waste being able to reduce SO_2 and NO_X emissions compared to coal (EPA/NREL 2009). Especially the sulphur contents of the wood fuels are lower.

The extent of particulate matter emissions depend on the completeness of the combustion and the used controls, with large scale plants generally having a more complete combustion and more effective control measures compared to small scale plants (Obernberger and Thek 2010, EEA 2013). Mercury emissions from biopower plants are significant less compared to coal-burning plants, while particulate matter emissions (fine particles, PM2.5) may be higher from biopower and, in particular, bioheat (EPA/NREL 2009). Also, the emissions of thoracic particles (PM10) may be significant, especially in small scale units for heat production. Even if highly efficient and properly operated, traditional log stoves produce significant air emissions, especially fine particles (PM10) and black carbon, which also have comparatively high short-term global warming implications (EPA/NREL 2009). Emissions of nitrous oxide from smaller units may also increase NO_x loads locally.

Particulate matter consists of range of substances, and the impact on health is often associated with exposure to PM2.5 or PM10, which are again associated with black carbon. Health studies have shown that black carbon is a more efficient predictor of health effects estimates compared to undifferentiated particulate matter (Janssen, Gerlofs-Nijland et al. 2012). For small-scale heating, well-operated automatic heating systems using wood fuels or miscanthus have the lowest particulate matter emissions compared to manually operated systems and triticale-based pellets (Schmidl, Luisser et al. 2011). Emissions of PM10 for automatic systems range from about 5-45 mg/Nm^3, highest at start up and lowest when the system operates at full load. For manual systems emissions of PM10 range from about 80-480 mg/Nm^3.

The use of fertilizers, pesticides, and herbicides for energy feedstock production can also result in emissions of for example particulate matter (PM), nitrogen and sulphur compounds, heavy metals, and volatile organic compounds (VOCs) (EPA/NREL 2009).

Finally, a specific problem exist at the level of the feedstock producer and biomass processor, where there may be air quality issues; handling of biomass often has health implications for workers due to exposure to dust and production of spores in stored biomass (Schlunssen, Madsen et al. 2011).

Air pollution is transboundary in nature, and already in the 1960s, it was demonstrated that acidification of Scandinavian lakes was linked to sulphur emissions in continental Europe. In the subsequent years, studies confirmed that air pollutants can travel several thousands of kilometres before they are deposited and cause damage. These problems led to the launch of the Convention on Long-range Transboundary Air Pollution in 1979, which is an international legally binding agreement dealing with air pollution. The Convention includes specific protocols on for reduction of emissions of sulphur, nitrogen oxides, Volatile Organic Compounds (VOC), heavy metals, and Persistent Organic Pollutants (POPs).

The convention does not address air pollution from bioenergy production specifically, but as a direct or indirect result, national or regional legislation now set thresholds for emissions of e.g. sulphur, nitrous oxides, and dust matter from energy producing plants, including bioenergy, e.g. (European Commission 2010). The limits of dust emissions in biomass fired plants set by (European Commission 2010) is 20-30 mg/Nm^3 for plants with a thermal output higher than 50 MW. Regular updating and information exchange on lists of Best Available Technologies (BAT) should ensure that best techniques are commonly used. It is also encouraged that national permit conditions are reconsidered regularly and updated if new or updated BAT conclusions have been adopted. Small scale energy production is exempted from this legislation.

Air quality is usually not included in frameworks for Sustainable Forest Management (SFM), while it is sometimes a part of standards for sustainable biomass or bioenergy, for example the standard of the Roundtable of Sustainable Biofuel (Roundtable on Sustainable Biofuels 2010). The RSB standards stipulate two criteria for air, the first being that “Air pollution emission sources from biofuel operations shall be identified, and air pollutant emissions minimized through an air management plan” (Criterion 10.a.). The air management plan should address carbon monoxide, nitrogen oxides, volatile organic compounds, particulate matter, sulphur compounds, dioxins and other substances recognised as potentially harmful for the environment or human health. The plan shall identify all potential air pollution sources, describe their nature and any mitigation strategies that are employed, or rationales if mitigation strategies are not implemented. The operator is also encouraged to investigate and implement Best Available Technology (BAT) to reduce the air pollution, with BAT being interpreting in a local context and according to the scale and intensity of the operation. The operators that must comply with this criterion are feedstock processors and biofuel (biomaterial) producers.

The other RSB air criterion is that “Biofuel operations shall avoid and, where possible, eliminate open-air burning of residues, wastes or by-products, or open air burning to clear the land” (Criterion 10.b.). This criterion addresses feedstock producers and feedstock processors. Standards for SFM may also have criteria preventing the burning of residues, even if the motivations are likely not air quality.

8.8. Competition with food, feed and fibre

For first generation biofuel raw materials such as wheat, rape seed, soy, sugar cane and palm oil there may be direct competition with the use for food and fodder. For lignocellulosic feedstock, such as wood, there is no direct competition with food, but there might be direct competition with other uses, that also deserves attention, even if the ethical implications are less clear. For example, there may be competition with fuel wood for subsistence use in developing countries, and with small-dimensioned round wood currently used for pulp and paper.

Even if there is no direct competition with food, the production of lignocellulosic feedstock may nevertheless compete for agricultural land that could otherwise be used for production of food or feed (Rossi 2012, Prieler, Fischer et al. 2013), see also Figure 34. Policies may dedicate that energy plantations should be established on degraded lands to prevent competition with food production, but (Azar and Larson 2000) showed that for eucalyptus plantations in the Northeast of Brazil, the value of the higher yields expected on better lands generally outweighs the additional cost of associated with acquiring that land. There are also examples that production of wood for charcoal is combined with food production in agroforestry systems (Couto, Nicholas et al. 2011, Rossi 2012). Mwanukuzi (2009) also showed an example from Tanzania, where growing eucalypts and pines on grasslands prevented a farming system that enabled integration of grasslands, cattle keeping and crop production. In Europe, the cultivation of trees as energy feedstock has mostly been discussed for marginal and abandoned agricultural land.

The RSB standard includes a principle to safeguard food security: “Biofuel operations shall ensure the human right to adequate food and improve food security in food insecure regions” (RSB 2012, Principle 6), with two subordinate criteria: “Biofuel operations shall assess risks to food security in the region and locality and shall mitigate any negative impacts that result from biofuel operations” and “In food insecure regions, biofuel operations shall enhance the local food security of the directly affected stakeholders”. These criteria indicate a need to evaluate the situation from case to case.

Plantations, including trees crops for energy may also put pressure on lands with natural forests, leading to losses of biodiversity (Zhai, Cannon et al. 2012), but to the knowledge of the authors, it is not known which is more important, competition for agricultural land or pressures on forest lands.

An increased demand for biomass for energy might also create competition with other uses of biomass (material displacement)(Agostini, Giuntoli et al. 2013). Some studies find that increased use of forest biomass for energy, might lead to increased use of fossil resources in other production sectors as some of the wood resources are in use already and must be replaced if they are to be diverted towards energy applications (Agostini, Giuntoli et al. 2013).

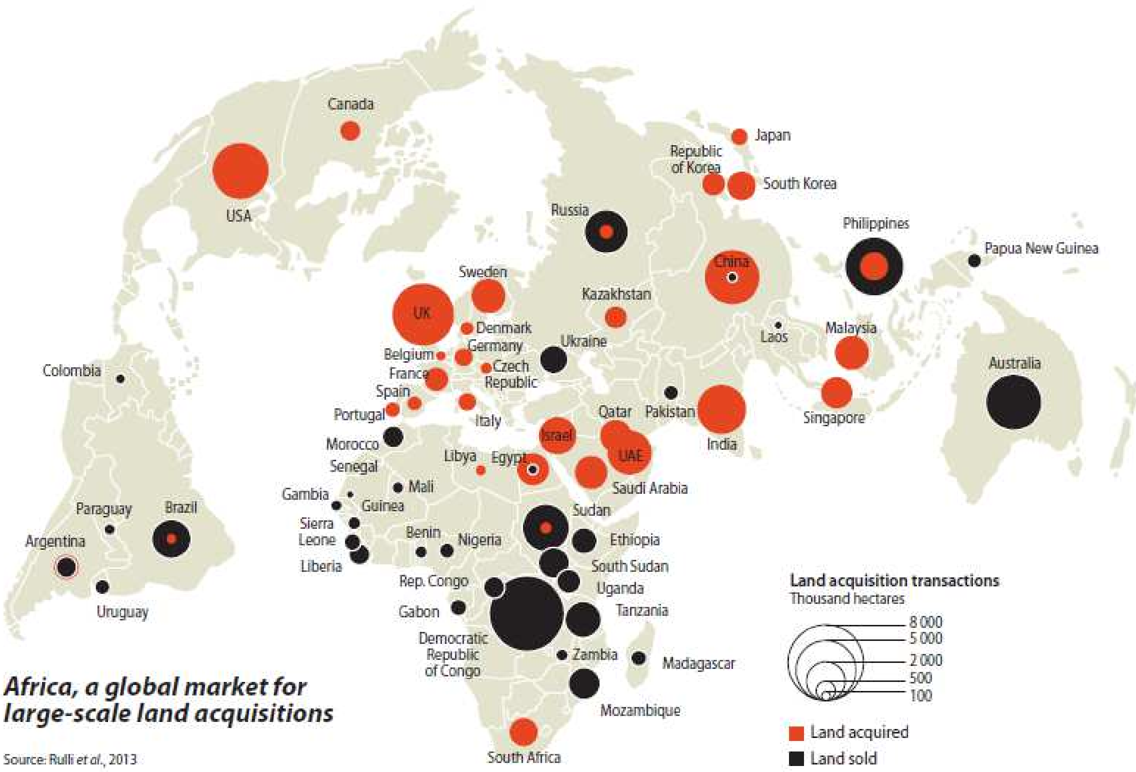


Figure 34. International land acquisition (GRID-Arendal 2013), http://www.grida.no/graphicslib/detail/africa-a-global-market-for-large-scale-land-acquisitions_2fd1.

9. Human forest disturbances

Greenhouse gases, biodiversity, soil, water, air etc. are all sustainability aspects that are important in relation to forests around the world. However, their ability (resistance and resilience) to maintain various ecosystem services and values differ, when they are subject to either natural or human disturbances. The functioning and organisms of some ecosystems are adapted to regular disturbances, while the functioning and organisms of other ecosystems rely on a stable environment. The severity of a disturbance will depend on its nature and extent and the ability of the ecosystem to resist or buffer it.

In their Global Forest Resource Assessment from 2010, (FAO 2010) identifies the most alarming forest-related developments. The first of the listed concerns is deforestation and natural loss of forest, which continues despite several initiatives were taken over the years to stop this development. An alarming trend is also the large loss of primary forest, often due to deforestation. This chapter seeks to explain deforestation patterns and some of the causes. Forests are also increasing affected by natural factors such as drought and insect pests, but these issues are addressed in chapter 11 for the specific regions.

9.1. The extent of deforestation and forest degradation

FAO (2010) estimates that during the 1990s approx. 13 million ha of forest were lost annually due to anthropogenic or natural factors. Of these about 4 million ha were primary forest. The corresponding figure was 16 million ha yr^{-1} for the previous decade. Even if the rate of deforestation as such shows a decreasing trend, it is still high. The regions most affected by deforestation include South America, Africa, Asia, Eastern Europe, including Russia.

In the case of forest cover change, the studies refer to the period 1980–2000 and are based on national statistics, remote sensing, and to a limited degree expert opinion. In the case of land cover change resulting from degradation in drylands (desertification), the period is unspecified but inferred to be within the last half-century, and the major study was entirely based on expert opinion, with associated *low certainty*. Change in cultivated area is not shown. Note that areas showing little current change are often locations that have already undergone major historical change (see Figure 1).

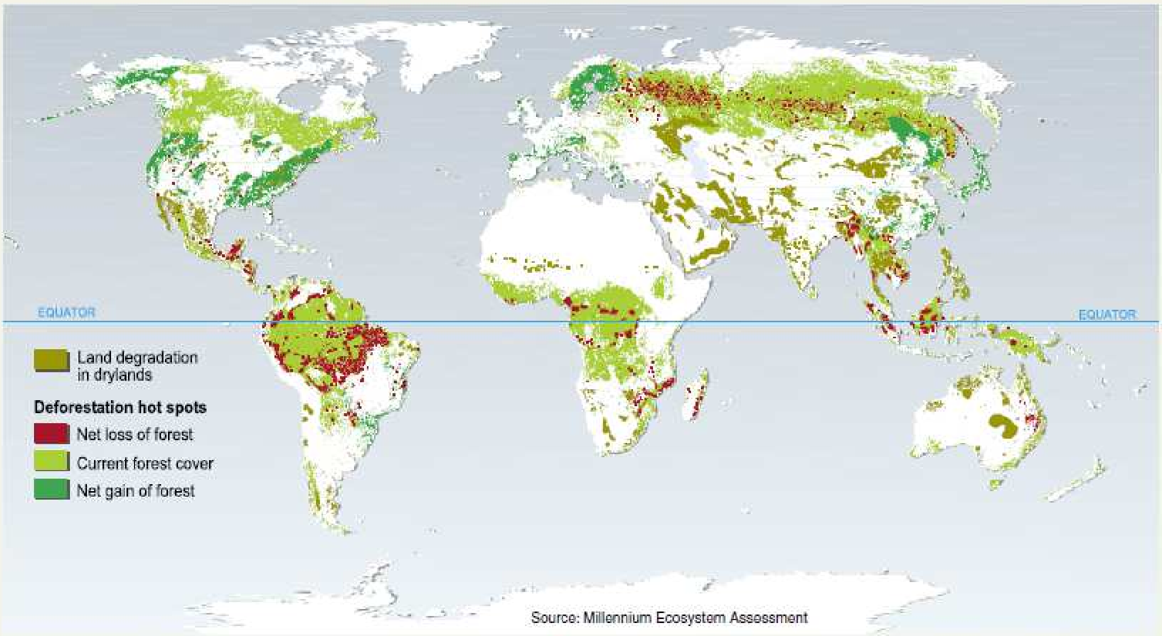


Figure 35. Locations reported by various studies as undergoing high rates of land cover change in the past few decades (MEA 2005).

9.2. Drivers of deforestation and forest degradation

The causes underlying tropical deforestation are rarely single-factored. Often both proximate and underlying causes are involved (Geist and Lambin 2002) (Figure 36), with proximate causes being human activities or immediate actions at the local level that originate from intended land use change and directly impact forest cover. The underlying courses are described as "*fundamental social processes, such as human population dynamics or agricultural policies, that underpin the proximate causes and either operate at the local level or have an indirect impact from the national or global level.".*

Geist and Lambin (2002)and Hosonuma, Herold et al. (2012) point towards agricultural expansion as the main proximity driver. Wood extraction is the most important course of forest degradation, and it also plays a role in deforestation, also in countries with reliable institutions and low levels of corruption (Damette and Delacote 2011). Damette and Delacote (2011) suggest that the relationship between timber harvesting and deforestation is due to harvested timber coming as a by-product of agricultural expansion, or that unsustainable forest management leads to land-use changes.

(Geist and Lambin 2002) observed that it is often interactions between the different drivers, rather than single factors, that lead to deforestation. State policies for land use and economic development often lead to expansion of land used for commercial crops and pastures, with such expansion requiring establishment of road networks and other infrastructure. As for wood extraction, a frequent combination of causes is the interaction between liberal granting of concessions, development projects, etc. by states in combination with corruption and poor implementation of forestry rules, with timber extractions also increasing the need for infrastructure (Geist and Lambin 2002).

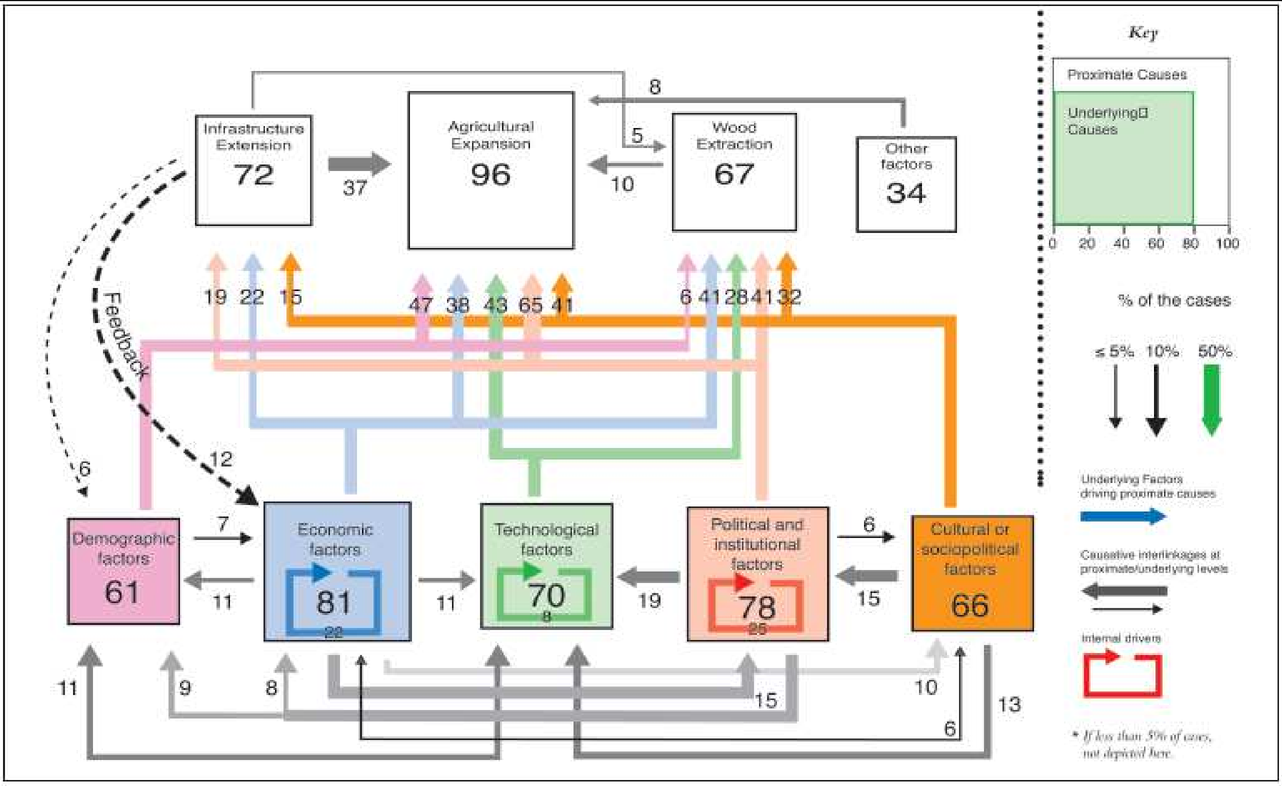


Figure 2. Causative pattern of tropical deforestation (n = 152 cases). Systems dynamics commonly lead to tropical deforestation. No single or key variable, such as population growth or shifting cultivation, unilaterally impacts forest cover change; synergies between proximate causes and underlying (social) driving forces best explain tropical forest cover losses. A recurrent set of mainly economic, political, and institutional driving forces underpins proximate causes, such as agricultural expansion, infrastructure extension, and wood extraction, leading to deforestation. Though some investigators have claimed irreducible complexity is the explanation, distinct regional patterns exist.

Figure 36. Causative patterns of tropical deforestation (Geist and Lambin 2002), figure 2.

It has been showed, that the speed, with which the deforestation is taking place, and its proximity drivers depend on the time that has passed since the deforestation activities started, while there are also regional and intra-regional differences. (Hosonuma, Herold et al. 2012) classifies countries according into four different groups according to the temperate phase of the deforestation (see also Figure 37):

- Pre-transition countries, which have a high forest cover and low deforestation rates.
- Early-transition countries, where forest cover is lost at an increasingly rapid rate.
- Late-transition countries with a rather small fraction of remaining forests, and a slow deforestation rate.
- Post-transition countries, where the forest area change rate becomes positive and forest cover increases through reforestation.

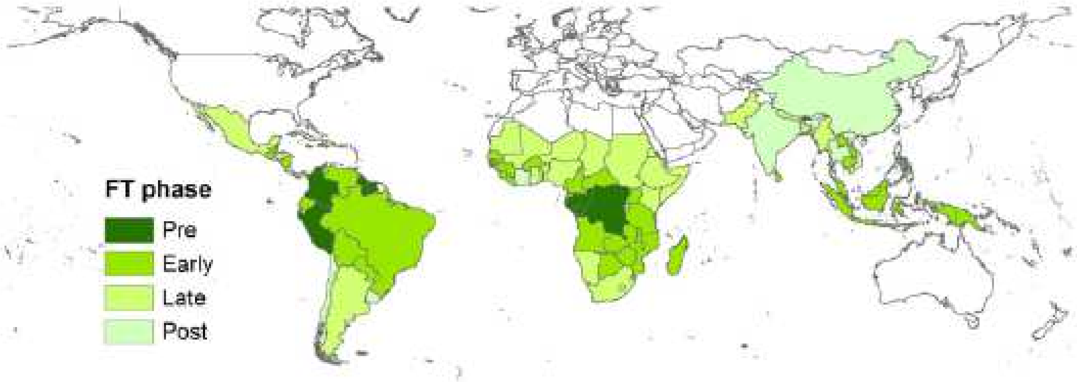


Figure 37. Spatial distribution of national forest transition (FT) phases in relation to deforestation: Pre-deforestation, Early and Late deforestation stage, and a Post-phase with reforestation (Hosonuma, Herold et al. 2012). Russia was not included in this study.

Mining and subsistence agriculture are usually the causes of a relatively limited deforestation for countries in the pre-deforestation phase, whereas commercial agriculture is the dominant cause of large-scale deforestation until the late-transition phase (Figure 38 a and b) (Hosonuma, Herold et al. 2012). The relative importance of subsistence agriculture does not change much over the different phases, while urban expansion and infrastructure are two major causes of forest clearance in countries that have reached the post-transition phase. Far the largest part of the deforestation takes place in the early-transition phase.

The drivers of forest degradation differ from those of deforestation (Figure 38 c). Degradation is generally caused by timber and logging activities in countries which are in the pre- and early states of deforestation. In the late-transition phase fuel wood and charcoal production and uncontrolled fires increase in importance, probably because all valuable timber has already been removed (Hosonuma, Herold et al. 2012).

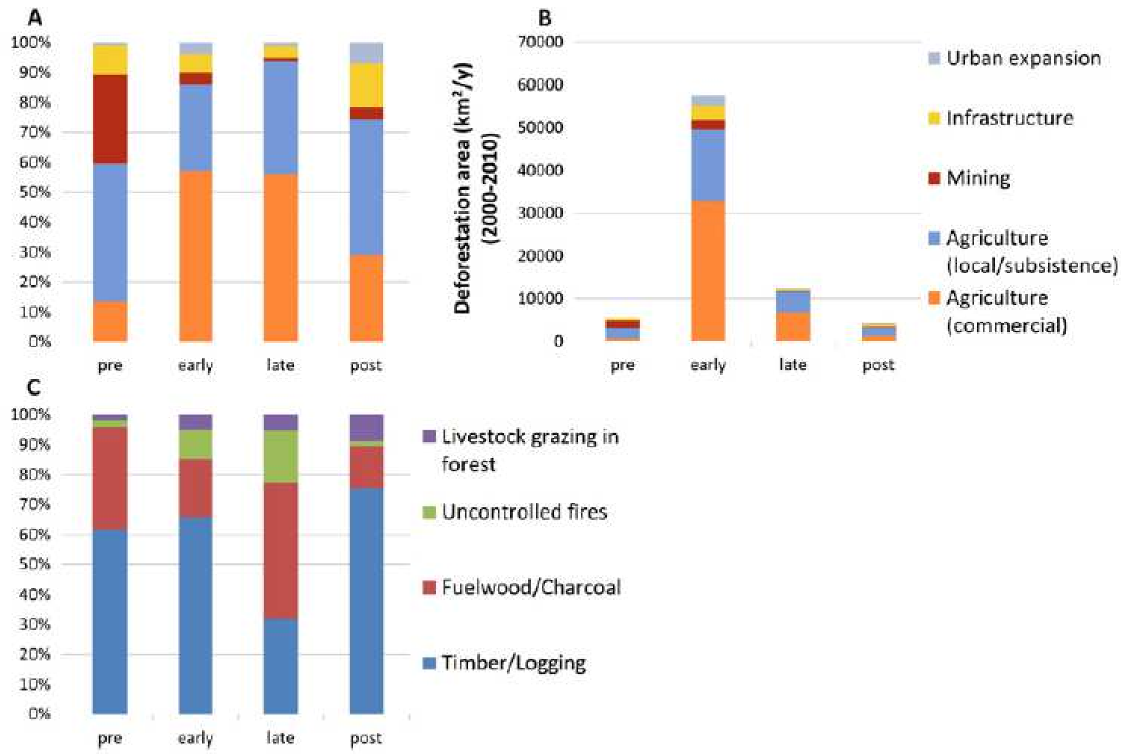


Figure 38. Forest transition phase estimations of the relative area proportion (A), and absolute net forest area change ($km^2\ yr^{-1}$; (FAO 2010)). for the period 2000–10 (B) of deforestation drivers, and of the relative disturbed forest area fraction of degradation drivers (C), based on data from 46 tropical and sub-tropical countries *(Hosonuma, Herold et al. 2012).*

There are also some regional differences in the drivers of deforestation activities that are, in part, related to the prevailing deforestation phases in the region (Figure 39 and Figure 40). Commercial agriculture is generally a more important driver in Latin America, while subsistence agriculture is equally important in Africa and Asia.

There are also regional differences with regard to the proximity drivers of forest degradation. Commercial timber extraction and selective logging operations are the main drivers of forest degradation in Latin America and subtropical Asia. In Africa, fuel wood collection and charcoal production are the main causes of forest degradation, even if timber harvesting also plays a significant role (Figure 39).

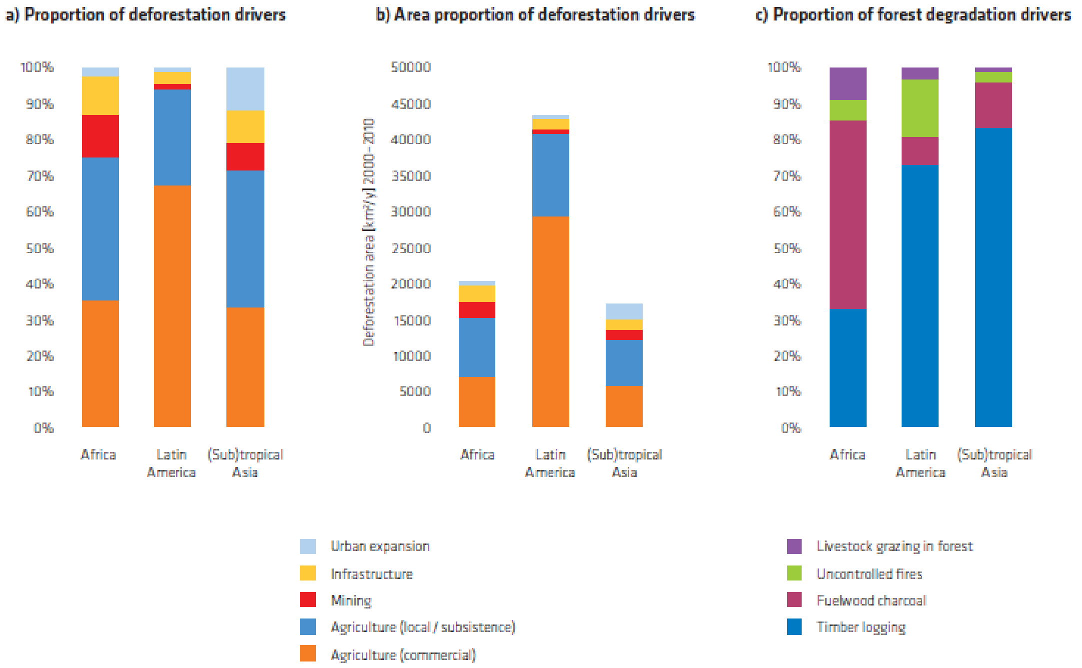


Figure 39. Drivers of deforestation and forest degradation in different regions of the world (Hosonuma, Herold et al. 2012, Kissinger, Herold et al. 2012).

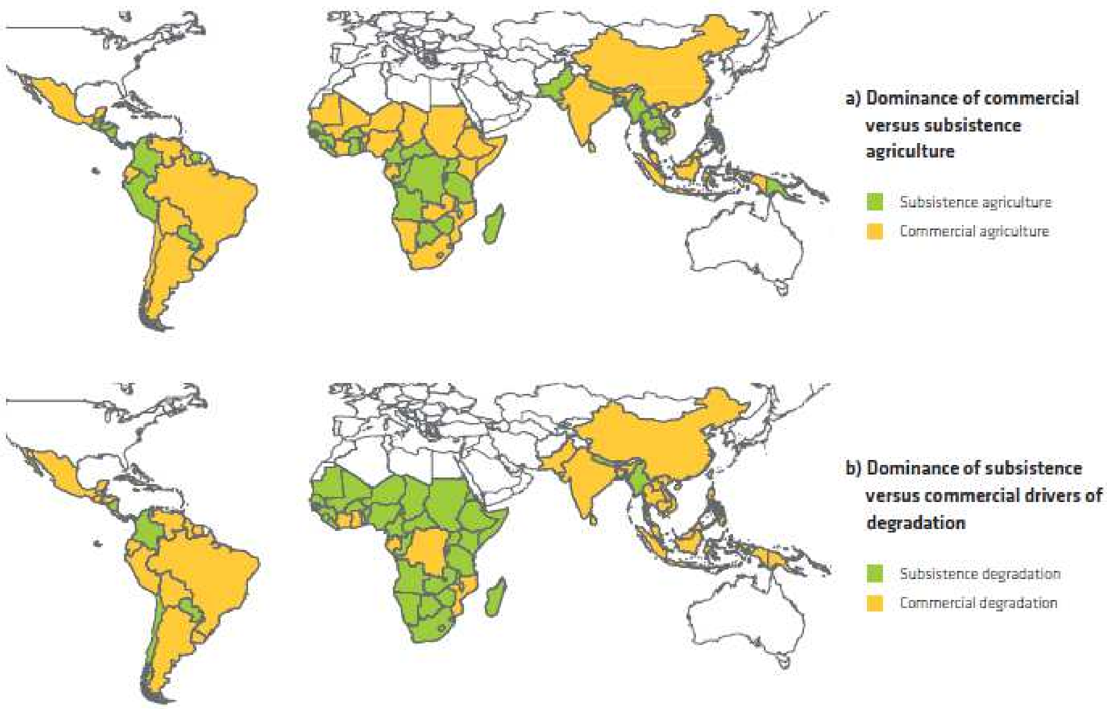


Figure 40. Spatial distribution of subsistence or commercial agriculture as drivers of deforestation and subsistence or commercial drivers of forest degradation (Kissinger, Herold et al. 2012).

9.3. Drivers of post-transitional reforestation

The forest post-transition phase, with its shift from net deforestation to net reforestation, was further studied by (Meyfroidt and Lambin 2011). In a review of literature they summarize findings from (Rudel, Coomes et al. 2005). They distinguish two nonexclusive pathways of forest post-transition: the economic development path and the forest scarcity path. The first path is associated with industrialization and urbanization, agricultural intensification in the most suitable regions of a country, and accelerated depopulation and agricultural decline in the regions least suitable for food production. This allows forest regrowth in marginal regions. The second path is associated with deforestation caused by agricultural expansion or wood extraction and a subsequent scarcity of forest products, raising timber prices that pave the way for more intensified forestry management systems, with timber needs being satisfied from limited areas of forest plantations. This saves the remaining forests from exploitation (Meyfroidt and Lambin 2011). Referring to a previous study by the same authors, they repeat three identified additional paths of forest post-transition, which are related to globalization, state forest policy, and finally smallholder, and tree-based land-use intensification, respectively.

(Meyfroidt and Lambin 2011) mapped the post-transition countries, and when the post-transition took place and found oldest post-forest transitions in Europe, and the most recent after 1970 in China, India, and some parts of the U.S. (Figure 41). Figure 40 suggest that Sub-Saharan Africa might soon follow, together with Argentina and Mexico, while these studies might be an indication that in countries that currently see the largest deforestation rates, the deforestation is like to continue for a longer period, unless effective measures can be found. The relative forest cover at turning point differed widely among countries, varying from very few percentages to about 40% in Europe and the Americas, while it ranged from about 10% to 65% in Pacific Asia.

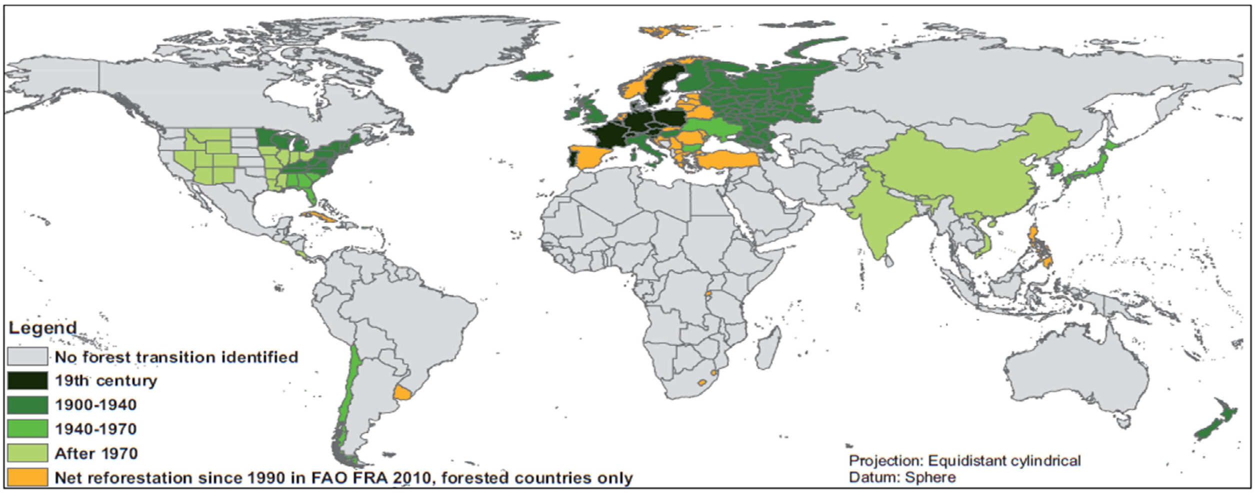


Figure 41. Periods of recent forest post-transitions. When there was no reliable study confirming the forest post-transition, data from FAO (1) were used to identify countries with net reforestation since at least 1990–2010 (note that reforestation may have started before 1990). Cases of forest post-transitions are presented at the country level, except for the United States and Russia for which the size of the countries and the internal heterogeneity of land-use history justify the representation of subnational forest transitions. Abbreviation: FRA, FAO Forest Resources Assessment (Meyfroidt and Lambin 2011) .

9.4. Globalization and leakage effects

In newer studies, the globalization is seen as a major driving force of deforestation (Lambin and Meyfroidt 2011). Lambin and Meyfroidt (2011) identified four underlying mechanisms, which are related to globalization. They call these the displacement, rebound, cascade, and remittances effects.

Factors leading to displacement include national land zoning policies for nature conservation. Protection of some areas leads to an increased search for cropland and wood products, which may trigger deforestation in other places (Lambin and Meyfroidt 2011). Displacement may also work cross borders, for example when developed countries adopt similar protection and conservation policies that lead to their increased import of food and wood products.

The European and North American (New England) shift from net deforestation to net reforestation in the 19th and early 20th centuries are examples of post-transitional reforestation that was facilitated by imports of timber and food from developing countries, and thus likely lead to displacement elsewhere (Lambin and Meyfroidt 2011). Modeling results also shows that environmental protection of forest in especially forest-rich countries may lead to a leakage effects abroad, usually in developing countries. The so-called “land grabs”, where large international agribusinesses or government buy large tracts of agricultural land in developing countries, may also displace subsistence farmers and push land use changes as deforestation.

The rebound effect occurs as a response to new technologies or other measures that reduce resource use. Such efficiency increases may have different impacts on pressures for land use changes. If the products from intensified production are consumed locally, the rebound effect tends to relief the pressure on land, as less land can produce the same amount. The opposite tend to be the case when products are consumed internationally. In this case, the increased profitability of agriculture will provide incitement for more actors to take advantage of the economic possibilities (Lambin and Meyfroidt 2011).

The cascade effects is land-use change is driven by a multiple of interacting factors in a sequence that also involves feedback loops. These factors may be rooted in local to the global driving forces, and are closely related to displacement effects (Lambin and Meyfroidt 2011). Finally, the remittance effect is due to outmigration from rural regions. This may for example lead to increased re-growth of forest vegetation in rural areas which become less populated.

With global interactions, the causes of deforestation and forest degradation have thus become increasing complex. Meyfroidt and Lambin (2011) conclude that *“a combination of technological innovations, sound land management policies, adoption of more efficient land-use practices, and changes in consumption patterns holds the potential to affect the supply of and demand for wood and agricultural products, and to promote a global restoration of forests.“*

9.5. Illegal logging

Deforestation and forest degradation caused by timber harvesting is often associated with illegal logging. Illegal logging is attributable to poor governance, not only in the countries where illegal logging takes place, but also in countries, where the processing takes place and in consumer countries (Lawson and MacFaul 2010). In producer countries weak institution with limited resources, poor law enforcement or inadequate forest laws and regulation as well as corruption seems to be major problems leading to illegal logging (Figure 42).

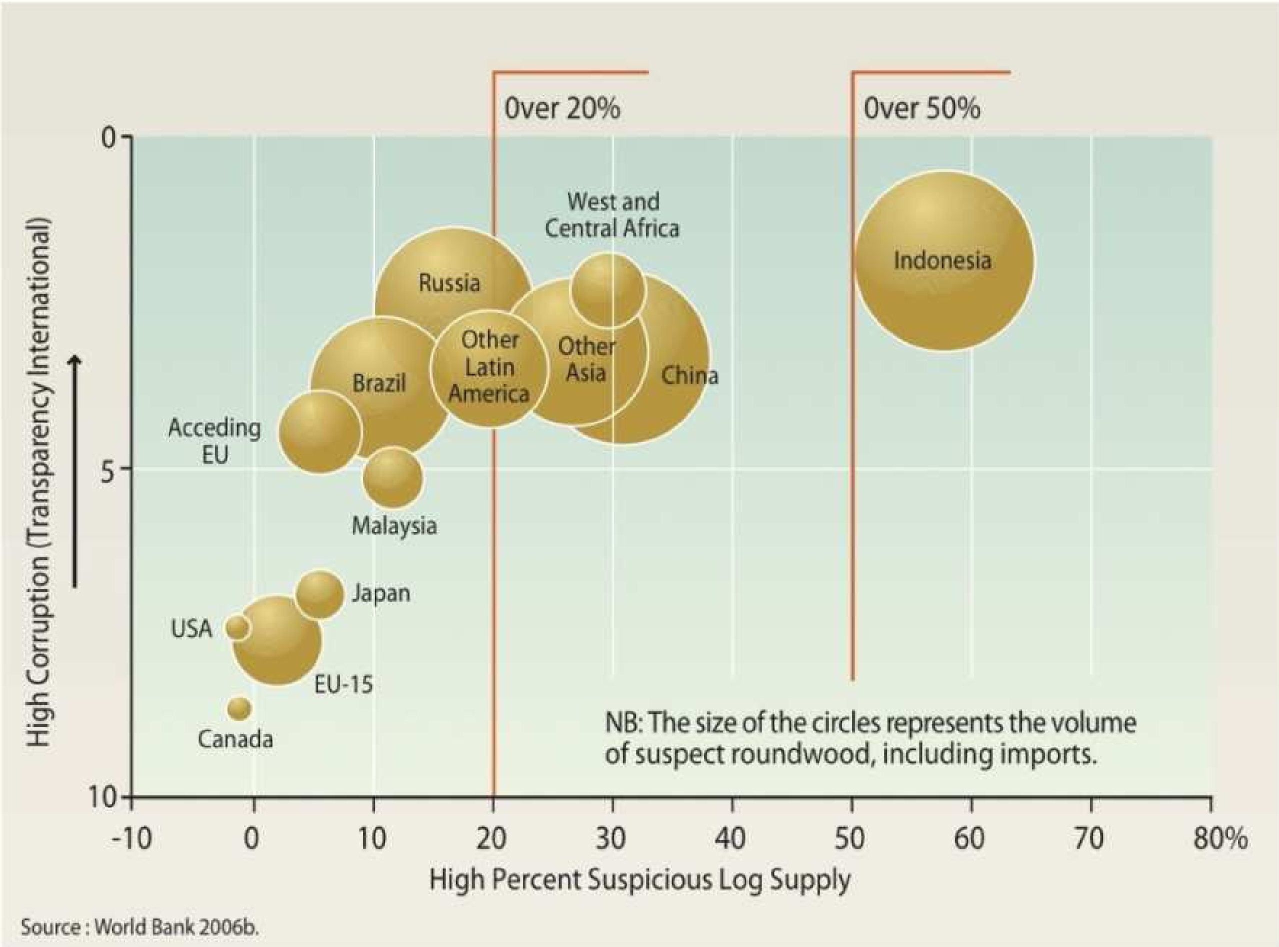


Figure 42.The relationship between suspicious timber supplies and corruption in different parts of the world (GRID-Arendal 2013), http://www.grida.no/graphicslib/detail/logging-and-corruption_ca51. Credited Philippe Rekacewicz assisted by Cecile Marin, Agnes Stienne, Guilio Frigieri, Riccardo Pravettoni, Laura Margueritte and Marion Lecoquierre.

The scale of illegal logging is difficult to estimate, but based on an analysis of a number of producer and consumer countries Lawson and MacFaul (2010) find that, on global scale, more than 100 million m^3 wood is perhaps illegally harvested annually. In the Brazilian Amazon region 35-72 % of harvested wood is found to be illegal. Corresponding figures for Cameroon are 22-35 %, Ghana 59-65 %, Indonesia 40-61 % and Malaysia 14-25 %. Among the regions importing timber to Europe, the Russia is reported to have the highest share of illegally harvested timber (Figure 43).

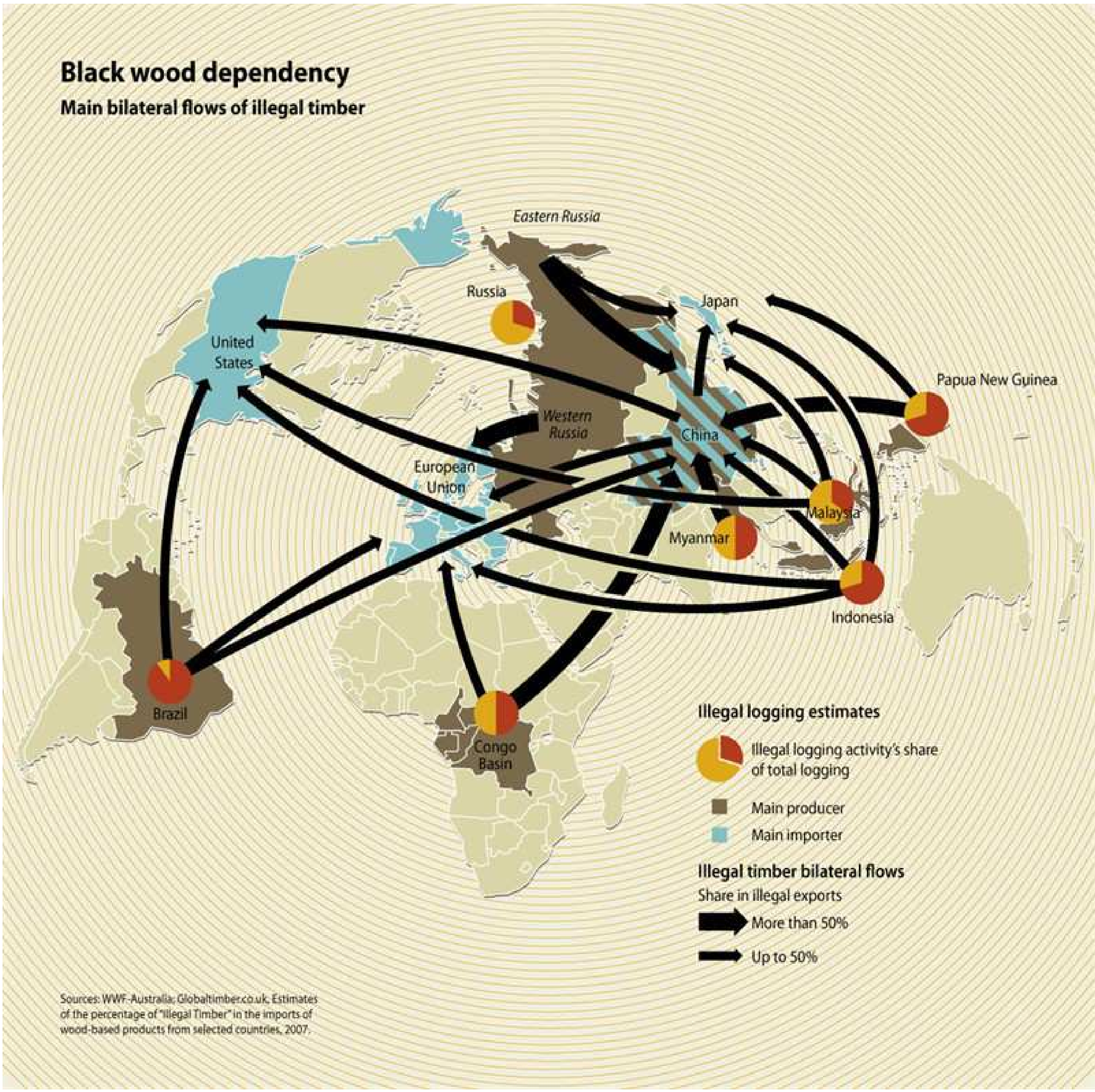


Figure 43.Estimated global flows of illegal timber (GRID-Arendal 2013), *http://www.grida.no/graphicslib/detail/black-wood-dependency_da5b*

According to Dijk and Savenije (2009), one of the key points in countries' combat of forest degradation and deforestation is to make good forest management a competitive alternative to the illegal activities, while at the same time ensuring that earnings reflect the costs and benefits of the production in a fair manner. Günter, Louman et al. (2012) suggest that payment for environmental services is promising tools to promote SFM. However, one of the most promising tools is probably REDD+ (Blaser, Sarre et al. 2011). While Reducing Emissions from Deforestation and Forest Degradation (REDD) is an effort to create a financial value for the carbon stored in forests, the REDD+ additionally includes the role of conservation and sustainable forest management for the enhancement of the forest carbon stocks (www.un-redd.org)

(Figure 44). This means that not only avoided deforestation can be compensated, but also improved forest management.

Figure 44.UN REDD partner countries (www.un-redd.org).

The Montréal Process, ITTO, FOREST EUROPE and UN FAO are networks that has long experience with monitoring and implementation of indicators for sustainable forest management. In relation to REDD+, they recommend that forest monitoring requirements and associated reporting be coordinated to avoid unnecessary burdens on the reporting parties, and that knowledge and experience be shared in acquiring data and getting overview trends in forest conditions for related purposes (Montreal Process Working Group, ITTO et al. 2012).

Also on the consumer side, actions are or can be taken to reduce illegal logging. Procurement policies and certification schemes have reduced the demand for illegal timber, and further reduction may require revision of trade legislation and control. In the European Union the FLEGT Voluntary Partnership Agreements with producer countries as well as the EU Timber Regulation of 2013, which aim at preventing illegal timber to enter the European market has reduced the demand. A particular challenge in combating illegal logging, however, is the import from processor countries i.e. countries that import illegal timber, process it and re-export it (Lawson and MacFaul 2010). While the EU Timber Regulation should prevent that from happening in the European Union a number of other large consumer countries, e.g. Japan, do not have adequate legislation in place. (Lawson and MacFaul 2010) estimate that the combined efforts of improved legislation and control in producer countries, procurement policies, voluntary agreements, trade legislation and control in consumer countries may have reduced illegal by almost 25 % from 2000 to 2009.

10. Forest and biomass sustainability governance

10.1. History of Sustainable Forest Management (SFM)

Many of the abovementioned challenges surrounding sustainability of forests and the forest management are not new or specific to wood fuels. Since the publication of the Brundtland report, Our Common Future (United Nations General Assembly 1987), the principle of sustainable development has gained general acceptance (Wiersum 1995), but principles for sustainable forestry was formulated already in German forestry literature in the 18th century, which introduced the "Nachhaltigkeitsprinzip" (Wiersum 1995), based on the principle that yields should not exceed the increment. In 1804 the German forestry lecturer Hartig also described sustainability as follows: 'Every wise forest director has to have evaluated the forest stands without losing time, to utilize them to the greatest possible extent, but still in a way that future generations will have at least as much benefit as the living generation'.

In the USA, the awareness of unsustainable forestry practices increased in the beginning of the 20th century. High tax rates on forestland gave timberland owners little incentive to hold on to the lands and reforest them after logging. Rather, it was cheaper to buy timberlands, log them, and then walk away and default on the taxes. By the 1930s, in response to these practices, the former chief of the U.S. Forest Service Gifford Pinchot and other foresters demanded that the federal government take over private timberlands as the best way to assure a future timber supply (www.treefarmsystem.org).

In response to the twin threats of forest fires and government regulation of private forestlands, the American Tree Farm System was established, with the first official tree farm being established by the Weyerhaeuser Timber Company that set aside 120,000 acres near Montesano, Washington, to test their theories about fire control and reforestation (ATFS 2013).

Concern over deforestation and destruction of forests in Africa led to the creation of the African Timber Organization (ATO) in 1976. ATO is an intergovernmental organization for cooperation on forestry issues relating to its 14 member countries, which hold over 75% of the tropical natural forests on the African continent. One of the major objectives of the ATO is to promote the production and trade of African timber within the framework of sustainable forest management (ITTO 2003). A similar initiative was taken for other tropical forest and in 1983 the International Tropical Timber Agreement was opened to signature with the aim of improving forest management, wood processing and sustainable utilization, encouraging also reforestation and conservation tropical forests and their genetic resources (United Nations 1983). Out of this the collaboration International Tropical Timber Organization (ITTO) was formed in 1986. ITTO has 56 member governments (and the European Community), which collectively represent 90% of the world tropical timber trade and about 80% of the world's tropical forests (ITTO 2003), and in 1992, the ITTO published the ITTO guidelines for the sustainable management of natural tropical forests, developed as a tool to monitor, assess, and report on progress in sustainable forest management for tropical forests (montrealprocess.org/The_Montreal_Process/About_Us/history.shtml).

In Europe, the First Ministerial Conference on the Protection of Forests in Europe was held in Strasbourg in 1990, on the initiative of France and Finland. The conference was attended by 30 European countries and the European Community as well as several intergovernmental observer organisations. Recognising the need for cross-border protection of forests in Europe, the participants agreed on six resolutions. The

Strasbourg Resolutions focused particularly on technical and scientific co-operation in order to provide the necessary data for common measures concerning European forests (www.foresteurope.org).

In 1992, United Nations Conference on Environment and Development (UNCED) in Rio again set a global focus on sustainable development, and a number of global agreements were made, including Agenda 21, the Climate Convention, the Convention on Biological Diversity and the Convention to Combat Desertification. At this occasion also the Forest Principles were formulated as a 'Non-Legally Binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of All Types of Forest'. At the time of the 1992 Earth Summit, countries had developed a series of principles for sustainable forest use, but the forest principles were the first global consensus on forests, dealing with protection of forests for environmental and cultural reasons. However, many Northern countries had hoped for a legally binding convention, but negotiations were protracted by a tension between the global North and South over access to finance and technology for the preservation of forests negotiations (Humphreys 2008).

Following the UNCED conference in Rio and the publishing of the ITTO guidelines in 1992, there was an obvious need to develop similar principles and guidelines appropriate for temperate and boreal forests. This lead to the agreements under the Montreal Process and further development of agreements by The Ministerial Conferences on Protection of Forest in Europe (now 'Forests Europe'). The Montréal Process Working Group (MPWG) was launched in 1994 and immediately set the task to develop a set of criteria and indicators to cover the temperate and boreal forests within its member countries. The current 12 member countries represent 33% of the world's population, 83% of the world's temperate and boreal forests, 49% of the world's forests, and 45% of the world's wood products (https://montrealprocess.org/The_Montreal_Process/About_Us/history.shtml).

The Earth Summit in Rio provided a forum for many non-governmental organizations to come together and gather support for a non-governmental, independent and international forest certification scheme. The idea was already put forward in 1990, when representatives from environmental and human rights a group of organizations met with a group of timber users and traders in California in 1990 to discuss concern about accelerating illegal logging, deforestation, environmental degradation and social exclusion. The failure of Governments to reach consensus in the form of an international legally binding agreement for forests caused both disillusionment and an opportunity, and NGOs such as WWF-International turned their attention to industry for a more meaningful governance-orientated resolution to the problem of deforestation. Following intensive consultations in ten countries to build support for the idea of a worldwide certification system, the FSC Founding Assembly was held in Toronto, Canada in 1993 (https://ic.fsc.org/our-history.17.htm). Today, FSC certifies forest management globally.

The FSC system was strongly influenced by environmental and human rights groups and the U.S. forest sector saw a need for developing their own system. The Sustainable Forestry Initiative (SFI) was launched in 1994 as one of the U.S. forest sector's contributions to the vision of sustainable development established by the 1992 UNCED conference (SFI 2010). Its original principles and implementation guidelines began in 1995, and it evolved as the first SFI national standard backed by third-party audits in 1998.

After these first intergovernmental processes and forest management certification systems had been established, a cascade of other systems followed in other parts of the world. Today there are nine intergovernmental processes on sustainable forest management (Figure 45), http://www.fao.org/forestry/ci/16834@45449/en/), even if the Montreal process and Forests Europe remains the most active processes, with national and regional level reporting taking place on criteria and indicators (C&I) of these frameworks. There is much agreement in the literature on the importance of C&I in, for example, Latin America for increasing the awareness of sustainable forest management and getting the principles into forestry legislation and having them implemented in the field. (Günter, Louman et al. 2012). This has also been the case in Europe (FOREST EUROPE, UNECE et al. 2011).

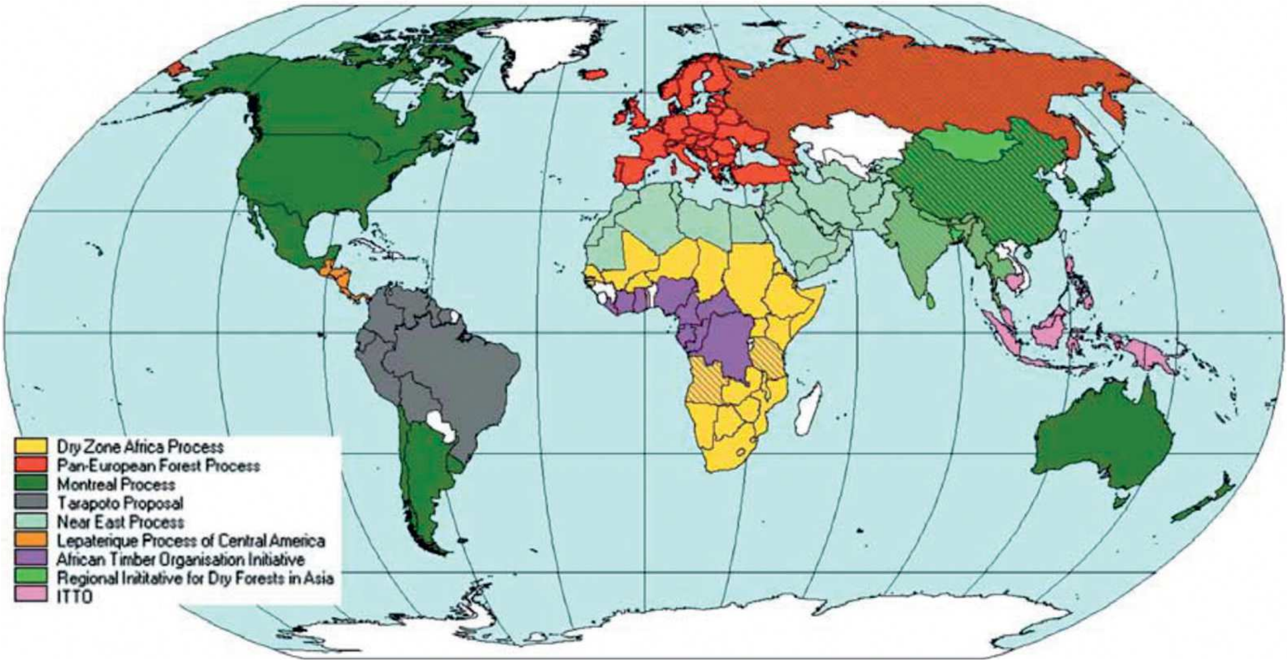


Figure 45. Countries involved in the nine international processes for Sustainable Forest Management (Wilkie, Holmgren et al. 2003). Several countries are members of more than one process, e.g. Russia, which is a member of both the Montreal process and FOREST EUROPE.

Voluntary certification also took a step forward in 1999, when representatives from the forest sector in Europe established the Pan-European Forest Certification Council (PEFC). Later, as the programme expanded its scope outside Europe, it changed its name to "Programme for the Endorsement of Forest Certification schemes". PEFC act as an umbrella system that endorses national forest certification schemes (www.pefc.org). Today, about 30 countries have national schemes endorsed by PEFC, including ATFS and SFI in the USA, and more schemes are being added almost every year. FSC and PEFC are now the dominating forest certification systems globally, with one third of the world's certified forest being certified under FSC, and two third being certified under a PEFC system. About 8% of the world's forests are certified today (Stupak, Lattimore et al. 2011).

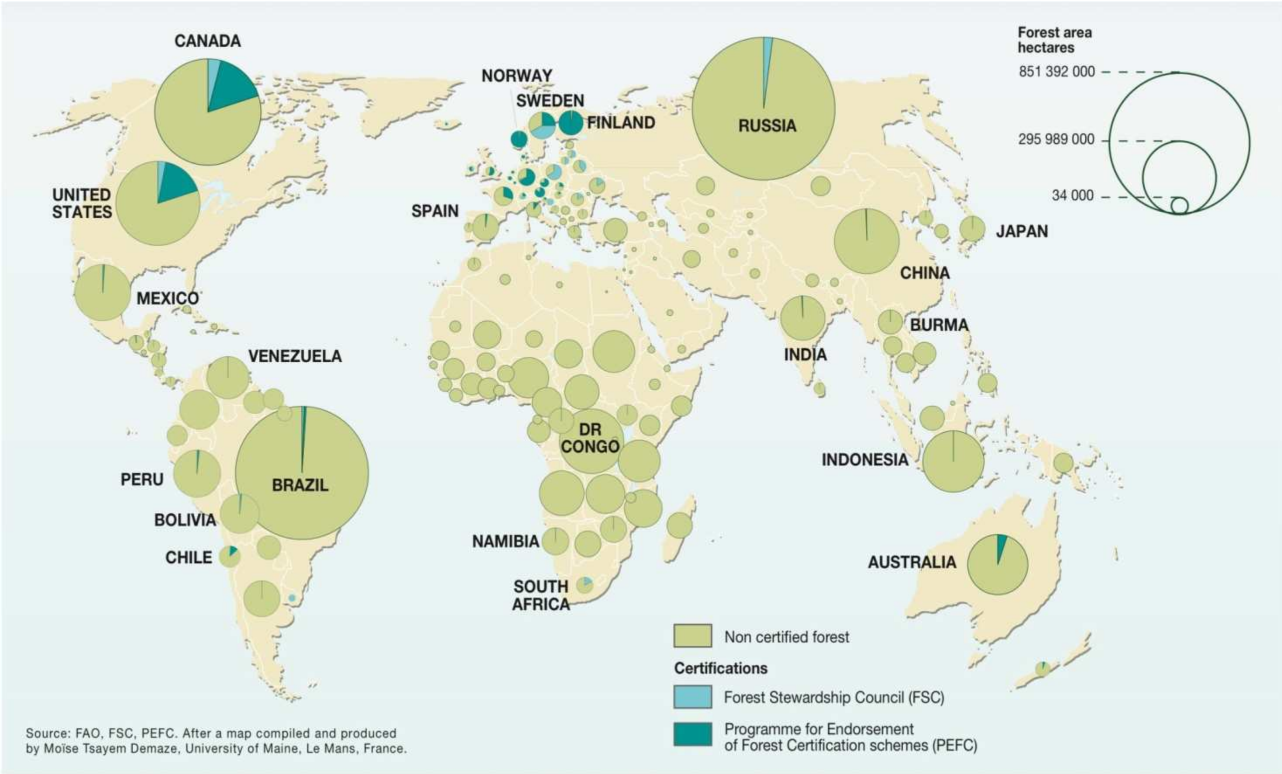


Figure 46. The share of certified forest area by country. The map probably overestimates the amount of certified area somewhat, as a part of the forest area is double certified. In Indonesia, part of the land may also be certified according to the LEI system. Note also that in a country like Canada, there are very large areas of unmanaged forest, for which forest certification is not (yet) relevant. (GRID-Arendal 2013), http://www.grida.no/graphicslib/detail/very-little-forest-area-is-certified_bd83. Credited Philippe Rekacewicz assisted by Cecile Marin, Agnes Stienne, Guilio Frigieri, Riccardo Pravettoni, Laura Margueritte and Marion Lecoquierre.

In May 2007, the United Nations Forum on Forests (UNFF) adopted the Non-legally Binding Instrument on All Types of Forests (NLBI) (FAO 2011). The instrument is considered a milestone, as it is the first time Member States have agreed to an international instrument for sustainable forest management. The instrument is expected to have a major impact on international cooperation and national action to reduce deforestation, prevent forest degradation, promote sustainable livelihoods and reduce poverty for all forest-dependent people.

10.2. SFM in national policy and legislation

FAO (FAO 2010) reports that significant progress has been made during the last decades in developing forest policies, laws and national forest programmes, and that many countries have started or updated these measures since 2000 (Table 4). About 80% of the 233 countries reporting to the Global Forest Resource Assessment give information on their forest governance, and of these about 93% report that they have legislation covering forests, either as a specific national forest law (156 countries), specific subnational laws (6 countries) or under other legislation (17 countries). Countries without forest legislation are usually small island states (FAO 2010).

Table 4. Number of countries with national forest policy, national forest programme, and national forest law, 2008 (FAO 2010).

Region/subregion	National forest policy			National forest programme			National forest law			
	Exists	Does not exist	No data	Exists	Does not exist	No data	Specific forest law	Incor-porated in other law	No law	No data
Eastern and Southern Africa	15	5	3	15	5	3	17	1	2	3
Northern Africa	4	2	2	3	2	3	5	1	0	2
Western and Central Africa	21	3	2	21	1	4	21	1	1	3
Total Africa	**40**	**10**	**7**	**39**	**8**	**10**	**43**	**3**	**3**	**8**
East Asia	3	1	1	4	0	1	4	0	0	1
South and Southeast Asia	16	2	0	15	3	0	15	2	1	0
Western and Central Asia	11	8	6	11	9	5	17	1	2	5
Total Asia	**30**	**11**	**7**	**30**	**12**	**6**	**36**	**3**	**3**	**6**
Total Europe	**27**	**11**	**12**	**31**	**6**	**13**	**33**	**2**	**3**	**12**
Caribbean	10	4	13	8	6	13	10	3	2	12
Central America	6	0	1	6	0	1	6	0	0	1
North America	4	0	1	1	3	1	2	1	1	1
Total North and Central America	**20**	**4**	**15**	**15**	**9**	**15**	**18**	**4**	**3**	**14**
Total Oceania	**10**	**4**	**11**	**6**	**8**	**11**	**8**	**4**	**2**	**11**
Total South America	**8**	**6**	**0**	**10**	**4**	**0**	**12**	**1**	**1**	**0**
World	**135**	**46**	**52**	**131**	**47**	**55**	**150**	**17**	**15**	**51**

In addition to all the above-mentioned measures, many jurisdictions also have mandatory or voluntary forest management guidelines, water and soil protection guidelines, and also specific biomass harvesting guidelines. In some countries like Sweden, biomass harvesting guidelines have existed for decades, but the number of jurisdictions and Europe and especially in North America, that develop jurisdictional biomass harvesting guidelines is increasing rapidly (Stupak, Asikainen et al. 2008, Titus, Thiffault et al. 2012).

10.3. Recent developments in governance of biomass and forest sustainability

In the beginning of the 2000s, the use and trade of biomass for renewable energy was already increasing, and an early need to document sustainable sourcing was identified by the energy companies. Forest and agricultural certification systems and various systems for certification of renewable energy already included comprehensive or brief criteria for sustainable biomass production, harvesting or sourcing. In 2002, however, a Dutch energy company, Essent, Netherlands, launched a system dedicated to verify sustainable sourcing of biomass for energy, the Green Gold Label (GGL). Belgian Electrabel followed with their own system in 2005, and at about the same time Swiss École Polytechnique Fédérale de Lausanne (EPFL) took the initiative to establish the Roundtable on Sustainable Biofuels.

The development of these schemes has accelerated since the European Commission (EC) and the European Parliament decided on the Renewable Energy Directive (European Parliament and the Council 2009), which include sustainability criteria for transportation and other liquid biofuels; EU RED allows that voluntary certification systems are used for showing compliance with EU RED sustainability criteria, if the schemes have been approved by the EU. In July 2011, the EC recognized the first 7 voluntary schemes, and by July 2013, 14 schemes have been approved, including RSB. The approval of GGL is still pending, and new schemes are being developed (Figure 47). An overview of several relevant systems was given by (van Dam 2009).

- 1941 - American Tree Farm System (ATFS)
- 1983 - First International Tropical Timber Agreement (ITTA)
- 1990 - Ministerial Conferences on Protection of Forests in Europe (MCPFE)
- 1992 - Forest Principles at UNCED in Rio
- 1992 - Sustainable Agricultural Network (SAN)
- 1993 - Forest Stewardship Council (FSC)
- 1994 - Sustainable Forestry Initiative (SFI)
- 1996 - Canadian Standards Association's standard on SFM (CSA)
- 1997 - GlobalGAP (previously EUREPGAP)
- 2000 - Programme for the Endorsement of Forest Certification schemes (PEFC)
- 2002 - Green Gold Label (GGL)
- 2005 - Laborelec
- 2008 - Roundtable for Sustainable Palm Oil (RSPO)
- 2009 - EU RED
- 2010 - International Sustainability and Carbon Certification (ISCC), Bonsucro...
- 2011 - Round Table on Responsible Soy (RTRS), RSB, 2BSvs...
- ? - International Wood Pellet Buyers (IWPB)

Figure 47. Timeline for launch of selected major first international initiatives and sustainability certification systems for sustainable forest management or sustainable biomass. The year indicates when the system came into operation. Often the development of the system has started years before (own compilation, see also (Stupak, Lattimore et al. 2011, Goovaerts, Pelkmans et al. 2013).

Some of the systems approved by EU apply do not only address liquid biofuels, but also solid biomass fuels originating from forestry, for example GGL, ISCC, and RSB (Goovaerts, Pelkmans et al. 2013). The International Wood Pellet Buyers (IWPB) is an example of an initiative that is being developed specifically for a solid fuel. The EU has not yet decided on mandatory criteria for solid and gaseous biomass, but recommendations from the Commission are expected during 2014. Some countries, like Germany, UK and Belgium already decided on national criteria for solid biomass fuels, and the Netherlands have a voluntary system. These will probably be adapted to EC criteria, if such are finally decided. In the USA, the second Renewable Fuels Standard (RFS2) of 2007 also applies lifecycle greenhouse gas performance standards to ensure significant reductions of greenhouse gas emissions - but not for forest bioenergy.

	AT_ÖSG	AT_UFG	AT_ÖN9466	BE_FL-GSC	BE_Wall-CV	BE_BRU-CV	BE_FL-ES	BE_Wall-BSub	BE_PelletNorm	BE_SmallHeat	CY_170/2004	CZ_482/2005	DE_EEG	DE_BioV	DE_OSSI	DE_MAP	DK_GrGrowth	DK_CHP	ES_661/2007	ES_949/2009	ES_430/2004	FI_NREAP	FI_SustForest	FI_FITpeat	FR_BCIAT	FR_CRE	FR_FITE
Biomass production/sourcing				x	x	x			x								x					x	x		x	x	x
Transformation/pre-treatment				x	x	x			x													x	x				x
Transportation	x	x		x	x	x																			x	x	
Conversion to energy	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x

	FR_ITC	FR_LOAN	HU_FIT	IE_BES	IT_BL2008	IT_Reaut	IT_REDTr	IT_Frame	LU_FIT	NL_EIA	NL_LAP	NL_BVA	NL_FERTI	NL_SDE	NL_SDEplus	NL_BEMS	PL_draftCoO	PT_FIT	SE_OoEC	SI_EECHP	SI_EERES	SK_Boiler	UK_ROO	UK_RHI	UK_SBHS	UK_BCGS	UK_ECS
Biomass production/sourcing			x	x			x						x							x	x		x	x	x		x
Transformation/pre-treatment											x												x	x	x		
Transportation					x		x																x	x	x		
Conversion to energy	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	

Figure 48. Status of the EU Member States' implementation of national sustainability schemes. There 54 national sustainability schemes, mostly focusing on end-use efficiency, and only two focusing on the whole supply chain (Volpi 2011).

Apart from initiatives occurring within the context RFS2, or existing or expected EU legislation, several other initiatives address sustainable biomass, including solid and gaseous biomass, are being developed. One of these are the ISO 13065 standard (under development), and another is the Global Bioenergy Partnership (GBEP), which is not for certification of the individual economic operator (or a group of these) but for whole countries to monitor their status and progress of bioenergy sustainability at a national level. GBEP is a voluntary partnership among comprise 23 countries and 14 international organizations and institutions. It was established in 2008, and in 2011 partners agreed upon a framework with 24 sustainability indicators for bioenergy. The indicators are intended to guide any national analysis of bioenergy sustainability, thereby informing the decision making and facilitating the sustainable development of bioenergy. GBEP is also committed to avoid duplication and support consistency among different other relevant governance measures, such as the multilateral trade obligations (GBEP 2013). The GBEP indicators are currently being tested in selected countries (Colombia, Ghana, Germany, Indonesia, Netherlands and USA), and an activity group (AG2) has been established to share experiences and lessons learned from the pilot testing. GBEP has the potential to play a role similar to the international SFM processes, leading e.g. to more coordination and awareness among countries, being also a source of national data, that are useful for comparative international analyses.

There are some profound differences among the early established forestry and agricultural schemes, such as FSC, PEFC, SAN, and Global G.A.P., compared to the newer certification schemes and other initiatives aiming at sustainable bioenergy and biomass sourcing. Early systems were focused on sustainability of the land management and include detailed requirements related to sustained yield, soil and water quality and biodiversity, and often social aspects. They do not include LCA criteria for reduction of greenhouse gas emissions along the whole supply chain, as does the more recent biomass and bioenergy schemes, including all the schemes approved by the European Commission. Some forestry schemes addressing conservation of ecosystem carbon, but otherwise forestry schemes have hesitated to get involved in questions related to greenhouse gas emissions. With the rapid development of bioenergy scheme, forestry schemes are, however, now considering their role as schemes for showing compliance with bioenergy criteria, including LCA criteria for GHG emission reductions. For example, the SFI has a Task Force on the matter (http://www.sfiprogram.org/files/pdf/brian-kernohan-2008-09-25pdf/) and international PEFC addressed the issues at its recent stakeholder dialogue meeting in Vienna, November 2012 (http://pefc.org/news-a-media/general-sfm-news/1083-).

The sustainability challenges related to wood energy is likely to be one of the reasons that the FOREST EUROPE signatory countries took the initiative to establish the Intergovernmental Negotiating Committee (INC) for a legally binding agreement on forests in the pan-European region. INC is mandated to develop a legally binding framework agreement for forests that addresses the long-term sustainable forest management in Europe. The Committee was expected to complete its work by the end of June 2013, but at the last meeting 10-14 June 2013 in Warsaw, the Committee decided to suspend the negotiations, and instead resume in autumn. According to Confederation of European Forest Owners (CEPF), the European forest owners are disappointed that the process was not successful (http://www.cepf-eu.org/artikkel.cfm?ID_art=585).

A basic sustainability criterion in sustainable forest management is that the forest biomass must be legal. The new EU Timber Regulation and the Voluntary Partnership Agreements has been established as a part of the European Union's Forest Law Enforcement, Governance and Trade (FLEGT) Action Plan, and work together to combat illegal logging and improve forest governance (http://www.euflegt.efi.int/portal/). A number of countries have already concluded agreements with the EU, and are currently developing the systems agreed on, while other countries are still negotiating an agreement (Figure 49).

The EU Timber Regulation (EU TR) lays down requirements that legality of timber and wood imported to and traded within the EU must be verified using a due diligence system. The legislation came into operation in March 2013.

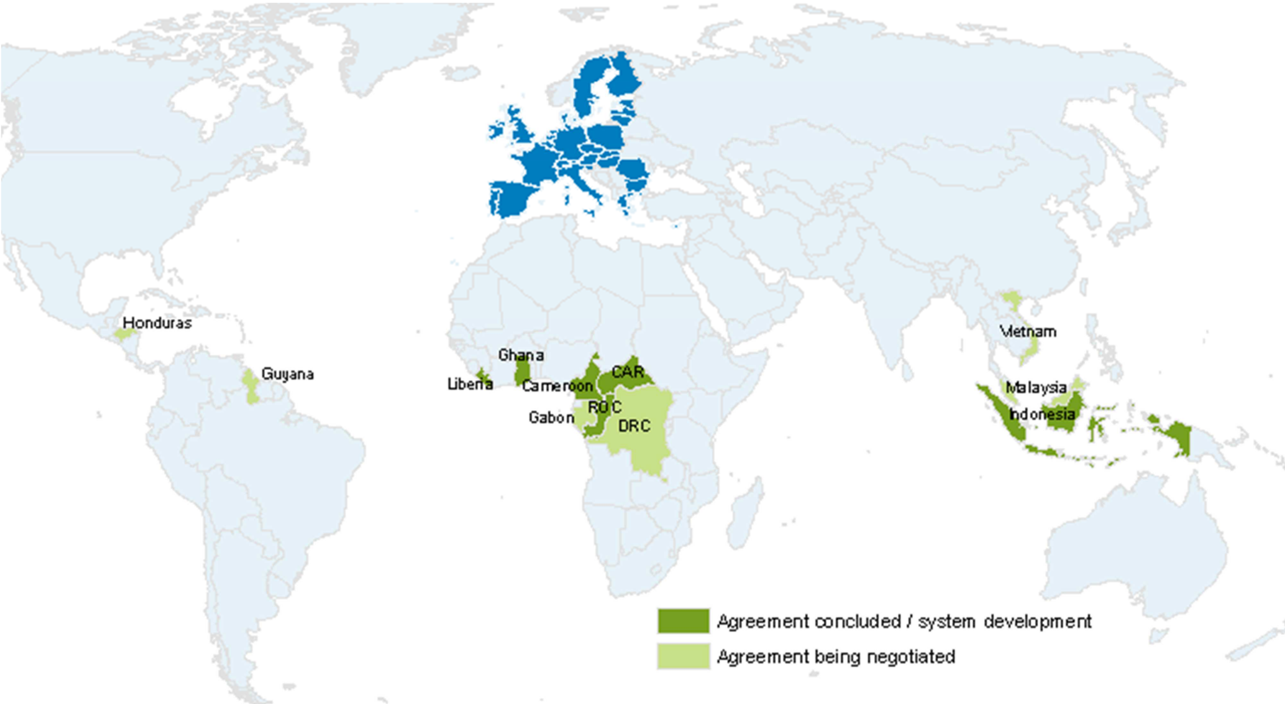


Figure 49. Countries that have concluded or are negotiating a Voluntary Partnership Agreement (VPA) with the EU under the EU FLEGT Action Plan (http://www.euflegt.efi.int/portal/home/vpa_countries/).

Forest certification systems are considering their role as means for showing compliance with requirements of the EU TR. Legality is already an integrated part of forest certification schemes, but there are additional requirements in EU TR with regard to the verification systems that need to be used. Currently, it seems that forest certification system will offer their members to check that all the requirements of the EU TR are being met, but with no application to the EU that they be approved as verification bodies (https://ic.fsc.org/eu-timber-regulation.46.htm).

The US Lacey Act has similar aims as the EU FLEGT. It was originally enacted to prohibit transportation of illegal animals including wildlife across U.S. State lines and international borders. In 2008, the act was extended to include timber, paper and other forest products, with sanctions for anyone in the U.S. who import, export, transport, sell, receive, acquire or purchase illegally-sourced forest products (http://www.euflegt.efi.int/portal/).

11. Wood biomass potentials and associated sustainability challenges in specific regions

Several countries plan that bioenergy should play a role in the transformation from a fossil dependent energy system to a renewable energy system, and the international trade with biomass is resultantly predicted to continue to increase. Importing countries ask from which regions their future biomass feedstock may come from, and if this is produced and harvested in a sustainable manner. Countries that have export potentials seek to identify which bioenergy feedstock that is physically, technically, economically, environmentally and socially available, and ask if their production will meet possible sustainability requirements of importing countries.

The aim of this part of the report is to review the potentials of selected regions in the world to act as future biomass sourcing countries for woody bioenergy feedstock, and to review which the specific challenges to wood fuel sustainability are in these regions. It was considered that for Danish imports, the most important near-term potential sourcing countries depend on the extent of the countries' forest area, the proximity to Denmark, the country's infrastructure and the sustainability characteristics of the wood fuel.

As shown in chapter 7, the current Danish import of wood fuels mainly takes place from the Baltic States, Russia, Poland, Germany and Sweden, and Southern Europe (Portugal and Spain). Larger imports of especially wood pellets from overseas countries are expected, predominantly from the south-eastern states of the U.S.A. and the eastern states of Canada in the short term. In a longer-term perspective, imports from the eastern part of South America, the western part of Africa (Ghana, Liberia, Ivory Coast), and perhaps South Africa are expected. We finally selected the following regions for a more in depths study: Europe, Russia, the USA, Canada, South America, and Western Africa. Europe was further separated into five sub-regions, North-western, Central-western, Eastern and Southern Europe, and the Baltic States.

For the selected regions, we review which forest types exist, the forest areas and resources, and the current wood and wood fuel production. Ownership structures and selected forest management aspects are touched upon. We also review which existing structures are in place to govern the sustainability of forests and wood and products and the specific sustainability challenges that exists for these forests and products. The sustainability aspects we focus upon include ecosystem carbon, biodiversity, soil, water, chemicals, air and competition for land and raw materials, especially land and raw materials for food production.

The review of forest types and resources is mainly based on the Global Forest Resource Assessment from 2010 (FAO 2010), while a main source of information for the review of sustainability issues are countries reporting to the international processes for sustainable forest management (SFM). The reporting is to these processes are relatively comprehensive for European countries, including Russia (FOREST EUROPE, UNECE et al. 2011), and reporting was also done under the Montreal process. For the U.S.A and Canada, comprehensive national reports that exist independently of the international processes made a baseline. Reporting by developing countries is sparse under the Montreal process and even more for the regional processes covering regions in Central and South America, Africa and Asia (Günter, Louman et al. 2012).

The reporting that exist is for sustainable forest management generally, even specific aspects related to energy wood are also often addressed. However, the information that deals with the specific environmental challenges related to wood fuel is less frequent, and even if much as been achieved, specific challenges still exist. In Europe, the different national forest inventories and lack of data for some criteria, among other, has been identified as a problem, and for example efficient monitoring of wood consumption for energy is missing (Martres, Carnus et al. 2011). Traditionally, sustainable forest management also does not include criteria for reduction of greenhouse gas emissions along the whole supply chain, with fossils as a reference fuel, or criteria regarding competition for land and raw materials. If available, relevant material on these aspects was included, as well as relevant supplementary literature for traditional SFM issues.

In the following, we refer to (FAO Forestry Department 2010) for further explanation of terms and definitions.

Assessing the sustainability of forest management is a complex undertaking, as it requires the quantification and combination of very different types of information on all aspects of forest management, and comparing the data to benchmarks. ECE/FAO, is at present, developing a method which could be applied in the next study of the State of Europe's Forests.

11.1. Europe

Information on sustainability aspects for different regions is given together in the last chapter on Europe. This chapter is based mainly on FOREST EUROPE's synthesis (FOREST EUROPE, UNECE et al. 2011) of national reporting to the process on sustainable forest management. FOREST EUROPE's synthesis is also giving a regionalised overview, but the regions being slightly different (Figure 50). Russia is also included in the review and will be briefly touched upon here, but is reviewed in more detail later.

The distribution of the European forest among countries is shown in Figure 50.

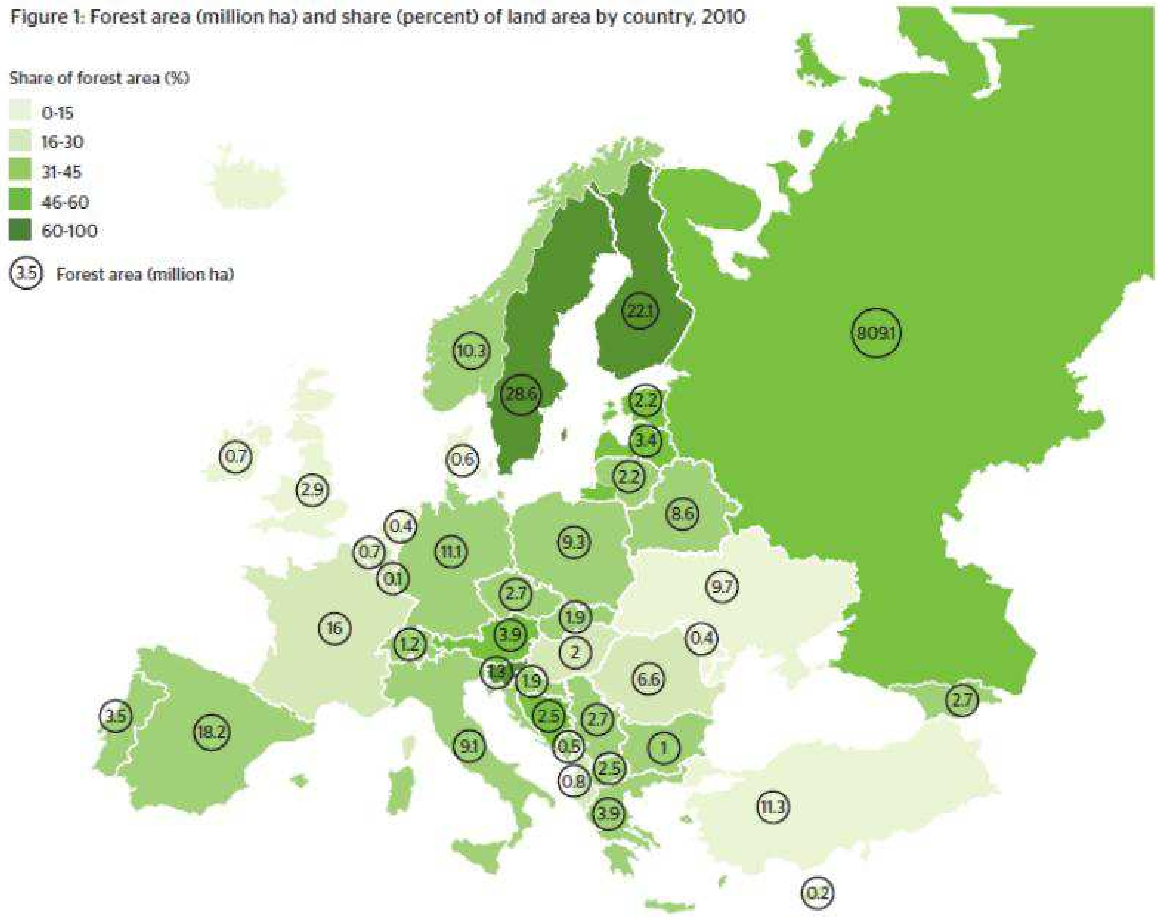


Figure 50. Forest area (million ha) and share (%) of land area for countries reporting to FOREST EUROPE (FOREST EUROPE, UNECE et al. 2011).

11.1.1. Northern Europe

11.1.1.1. Forest areas and types

The region is characterised by temperate broadleaf and mixed forests to the south and boreal forests in the north (UNEP, FAO et al. 2009). In a forest perspective the region is very inhomogeneous. The southern, predominantly temperate part is characterised by countries with little forest cover (11-12 %) and small forest areas (0.7-2.8 million ha). In the northern part countries have large forest covers (33-73 %) and large forest areas (10-28 million ha) (FAO 2010).

The total forest area in the region is 64 million ha of which 2.8 million ha are characterised as primary forest, 47 million ha as naturally regenerated forest, and 14 million ha as planted forest (FAO 2010).

All countries have seen a positive development in the forest area. Particularly in Ireland, the forest area has increased rapidly, with annual growth rates between 1 and 3% from 1990 to 2010. For the region as a whole the forest area has increased with 2.7 million ha since 1990 (FAO 2010).

11.1.1.2. Carbon

The total the amount of carbon stored in North European forests has increased from 10.2 billion tonnes in 1990 to 10.9 billion tonnes in 2010 (). The total amount is probably underestimated as no data on carbon in soil and litter are available for Norway. Due to their large forest area, Finland and Sweden contributes most to the region's carbon reservoirs. In Finland, in particular, a lot of carbon is stored in soil and litter (FOREST EUROPE, UNECE et al. 2011).

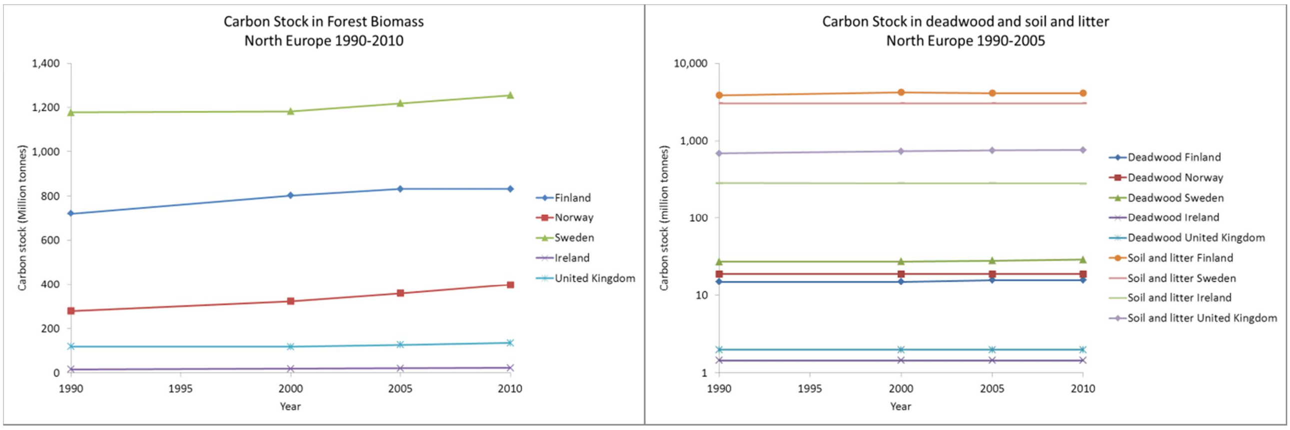


Figure 51. Carbon stock in biomass (left pane) and in dead wood and litter (right pane) in the forest in the North European region. Notice the logarithmic scale on the Y-axis in the right pane. Reference: (FOREST EUROPE, UNECE et al. 2011).

11.1.1.3. Ownership

Private ownership is predominant in the North-western European region except for Ireland (Table 5). Furthermore 2/3 or more of the privately held forests are owned by individuals and most of the rest by companies. In Norway and Sweden tribal communities own a minor fraction of the privately held forests.

Table 5. Ownership structure of North European forests (FAO 2010).

Country	Public	Private	Other
		%	
Finland	32	68	0
Norway	14	86	0
Sweden	24	76	0
Ireland	58	42	0
UK	35	65	0

11.1.1.4. Forest governance

North European forests are framed by well-developed legal and policy measures. Forest policies, national forest programmes and specific forest laws are enacted in all countries.

Table 6. Levels of protection of North European forests (FAO 2010).

	Permanent forest estate		Forest in protected area		Forest with management plan	
	1000 ha	%	1000 ha	%	1000 ha	%
Finland			1,925	9	14,497	65
Norway	421	4	167	2	4727	47
Sweden			1,435	5	28,203	100
Ireland	739	100	58	8	570	77
UK	2,881	100	145	5	1,870	65

The North European countries also have ratified a number of supra national declarations and agreements that may be relevant to various aspects of forest and wood sustainability. These include CBD[3], UNFCCC[4], Kyoto Protocol, UNCCD[5], ITTA[6], CITES[7], Ramsar[8], WHC[9], NLBI[10] (FAO 2010). To meet the CBD Strategic Plan for 2011-2020 that aim at reducing the loss of biodiversity, the EU adopted six regional strategic targets for 2020, and visions for 2050, see the section on biological diversity for details.

A large part of the forest area is certified according the FSC or a national system endorsed by PEFC (Table 7).

[3] Convention on Biological Diversity
[4] United Nations Framework Convention on Climate Change
[5] United Nations Convention to Combat Desertification
[6] International Tropical Timber Agreement
[7] Convention on International Trade in Endangered Species of Wild Fauna and Flora
[8] The Ramsar Convention on Wetlands
[9] World Heritage Convention
[10] Non-legally Binding Instruments on Forests, United Nations Forum on Forests

Table 7. Total forest area and certified forest area in Northern Europe. Some areas may be double certified.

	Total forest area		Forest area certified by FSC		Forest area certified by PEFC	
	1000 ha	%	1000 ha	%	1000 ha	%
Finland	22,157	73	430	2	21,068	95
Norway	10,065	33	254	3	9,126	91
Sweden	28,203	69	11,590	41	10,544	37
Ireland	739	11	447	60	0	-
UK	2 881	12	1,580	5	1,298	45

11.1.1.5. Wood and wood fuel production

In total net annual increment in 2010 in forests available for wood supply is estimated to 230 million m3 (FOREST EUROPE, UNECE et al. 2011). Ireland is not included as data on forest increment is not available. Annual felling (2010) is estimated to 162 million m^3 corresponding to an average exploitation rate of 70 %.

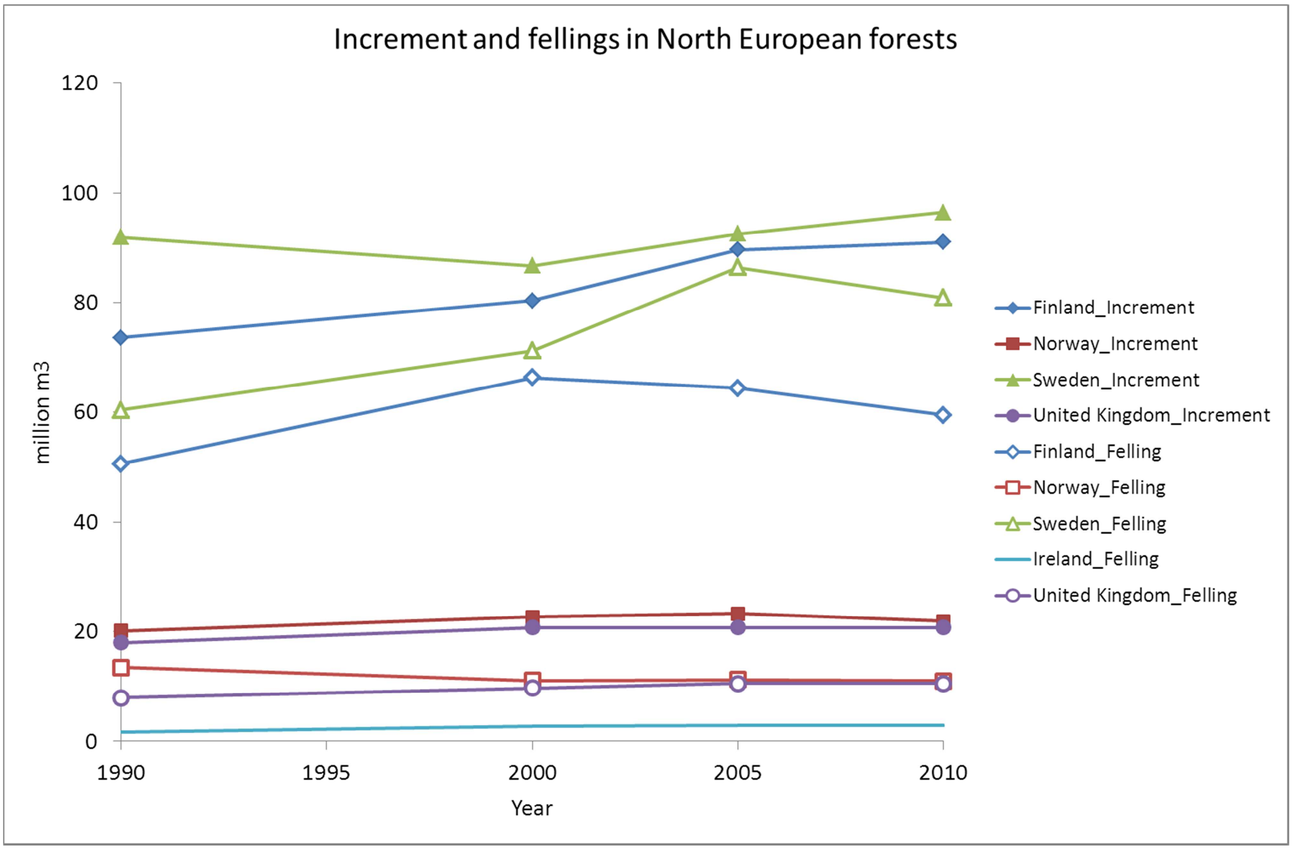


Figure 52. Annual increment and felling in North European forests in 1990, 2000, 2005 and 2010 (FOREST EUROPE, UNECE et al. 2011).

Exploitation rates differ between countries and vary over time. In Norway and UK has upheld a stable rate at app. 50 % for the last ten years, while the Finnish rate currently is 15 points and the Swedish another 20 points higher. Both countries, however, exhibit a decreasing trend (FOREST EUROPE, UNECE et al. 2011).

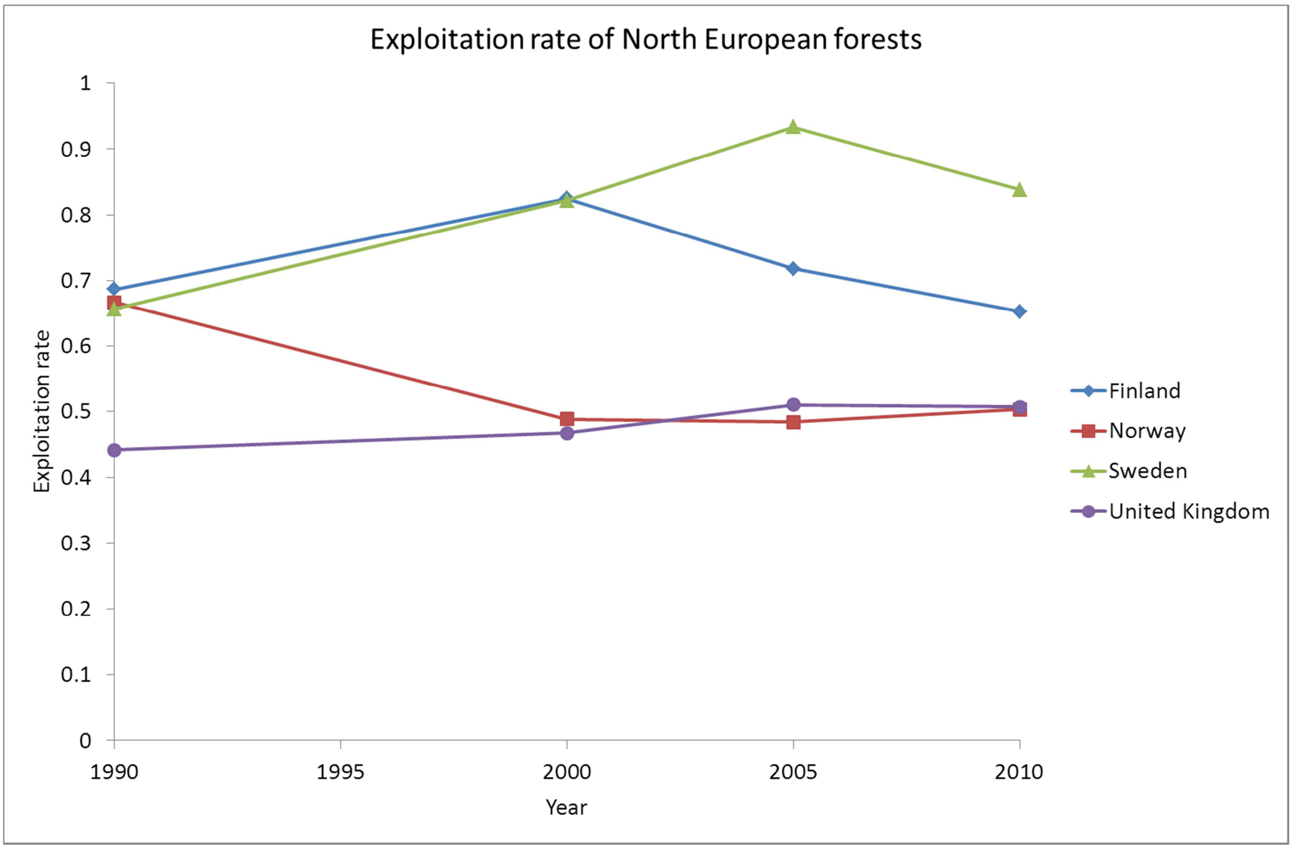


Figure 53. Exploitation rate (felling divided with increment) in the North European region. Data on increment in Ireland is not available (FOREST EUROPE, UNECE et al. 2011).

In all countries except Norway industrial wood production has increased since 1990. Also wood fuel production has increased except in Ireland (FAO 2010). The current (2011) total production of industrial round wood in the region is 131 million m^3 more or less evenly shared between coniferous and broadleaved species. Corresponding figure for wood fuel is 15 million m^3 in total with 56 % from broadleaved species (FAO 2012).

The pellet production capacity in Sweden by 2011 is estimated to 2.3 million tons, with a production of 1.35 million tons ((AEBIOM 2011, AEBIOM 2012) (Figure 54). The Swedish pellet production is completely based on wood industry residues (Cocchi, Nikolaisen et al. 2011). The Finish capacity is estimated to 650,000 tonnes, with a production of 310,000 tonnes based mostly on wood industry residues. Sweden and Denmark are the main markets for Finnish pellets. Norway has a capacity of less than 600,000 tonnes but utilizes very little of that capacity, with a production of 45,000 tonnes in 2010 (Cocchi, Nikolaisen et al. 2011). The current production in Norway is based predominantly on wood industry waste, but new capacity is build that will rely on imported wood chips from North America. Wood pellets are traded extensively between Norway, Denmark and Sweden.

For the UK data are limited, but the capacity in 2011 is estimated to 480,000 tons, with a production of 300,000 tons. Most plants operate on wood industry residues, but also wood waste, wood from short rotation forestry and forest thinnings go into the production. Denmark is by far the largest buyer of UK pellets. The Irish production capacity is very low, below 100,000 tons (AEBIOM 2011, AEBIOM 2012), with a utilization rate of 34 % (Cocchi, Nikolaisen et al. 2011).

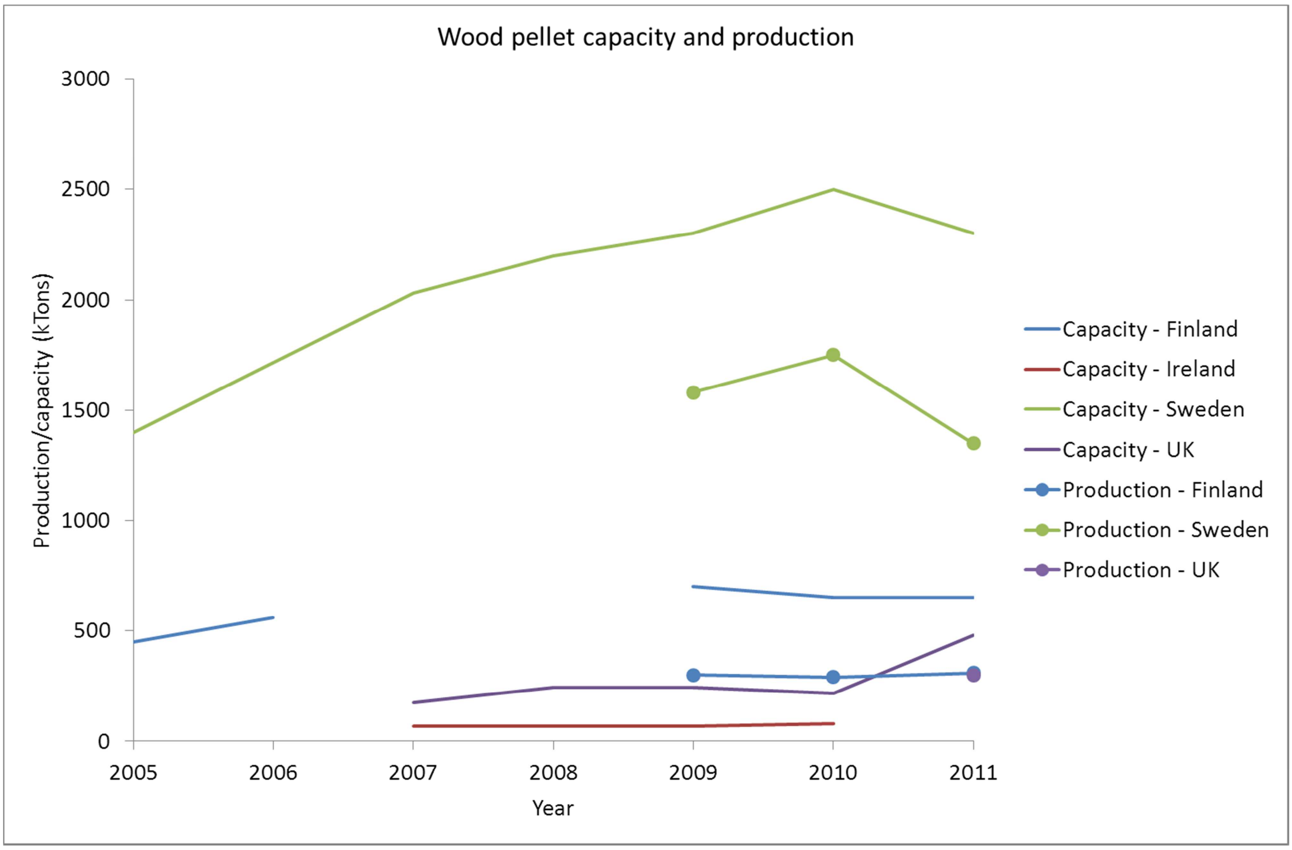


Figure 54. Pellet production capacity and production in Northern Europe. Based on statistical data from (AEBIOM 2011, AEBIOM 2012)

Summing up the total current production capacity in the North European region is around 3.5 million tons annually, with an increase in capacity primarily seen in Sweden and Norway.

Sweden, Finland and UK are among the 20 largest contributors to the Danish wood pellet import. Imports for Norway and Ireland cover 0.1 % or less of wood pellet imported from 2009-11. In total about 580 million kg have been imported from these five countries from 2009-11 (Danmarks Statistik 2012).

The North European region is also well represented in the Danish wood chips import. Sweden, UK, Norway and Finland are among the 20 biggest contributors. For the sake of scale Sweden has from 2003-11 exported 517 million kg wood chips to Denmark, which is between 35 and 55 times as much than the other countries mentioned (Danmarks Statistik 2012).

11.1.1.6. Wood resource potential

A number of assessments of wood based bioenergy resources have been made over the years, e.g. (Hetsch 2009), (Alakangas, Heikkinen et al. 2007), (Asikainen, Liiri et al. 2008), (Ericsson and Nilsson 2006), (European Environment Agency 2006), (Mantau, Saal et al. 2010), (Smeets and Faaij 2007). A recent review (Bentsen and Felby 2012) demonstrate the variability between studies caused by differences in assumptions, definitions and temporal and geographical scope. A number of recent estimates of forest resources available for energy are presented in Table 8. Direct comparison between studies must be done with caution. They include various fractions of wood resources and calculate different biomass potentials. Technical potentials as given by (Ericsson and Nilsson 2006) and (Böttcher, Dees et al. 2010) estimates the amount of biomass technically available with existing technology and constraints imposed by e.g. land availability, access, and crops. Some level of environmental constraints may also be applied. Techno-economic potentials (Alakangas, Heikkinen et al. 2007) are the fraction of technical potentials exploitable with a profit. Environmentally-compatible potentials (European Environment Agency 2006) are often also seen as sustainable potentials are a fraction of the technical potential constrained by environmental considerations. The potential given by (Hetsch 2009) estimate the amount of wood resource from primary biomass, primary and secondary residues, stumps and consumer waste available additional to the year 2005 consumption. This estimate indicates an unused resource potentially available.

As described above the biomass potentials presented in the Table 8 are not directly comparable. They do, however, rank the countries identically. The North European region, particularly Sweden and Finland, hold sway over large woody biomass resources. Ireland has very little biomass resources and probably also Norway.

Table 8. Overview of recent estimates of woody biomass resources in the North European Region.

Reference	Resource	Potential	Period	Unit	Finland	Norway	Sweden	Ireland	UK
(European Environment Agency 2006)	Forestry resources	Environmentally-compatible	2020	PJ	75		100	4	63
			2030	PJ	75		100	4	46
(Ericsson and Nilsson 2006)	Wood industry by-products	Technical	2010-20	PJ	~130		~150	<10	~30
	Forest residues	Technical	2010-20		~70		~80	<10	~15
(Böttcher, Dees et al. 2010)	Stem wood, branches, stumps, secondary residues	Technical	2005-10	PJ	442		332	12	105
	Aboveground residues	Technical		PJ	177		193	10	39
(Alakangas, Heikkinen et al. 2007)	Forest residues, industrial by-products	Techno-economic	2004	PJ	~100		~140	<10	~40
(Hetsch 2009)	Stem wood, forest residues, stumps, woody biomass outside forest, forest expansion, industry residue and post-consumer waste	Additional socio-economic supply	2020	Mm^3	18.4	5.5	16.9	0.7	11.0

11.1.2. The Baltic States

11.1.2.1. Forest types

The Baltic States (Estonia, Latvia and Lithuania) lies in the temperate broadleaf and mixed forest zone (FOREST EUROPE, UNECE et al. 2011). Forest covers 7.7 million ha corresponding to 44 % of the total area. 13 % (1 million ha) is classified as primary forest, 70 % (5.4 million ha) is naturally regenerated forest, and 17 % (1.3 million ha) is planted forest. In all three countries the forest area has increased from 1990 to 2010 (FAO 2010).

11.1.2.2. Carbon

The total carbon stock in the forests in the Baltic States has increased from 971 to 1155 million tonnes between 1990 and 2010. Carbon in soil and litter constitute the largest fraction of the total carbon reservoir. There are no data on the reservoir in Estonia, why the total probably is underestimated.

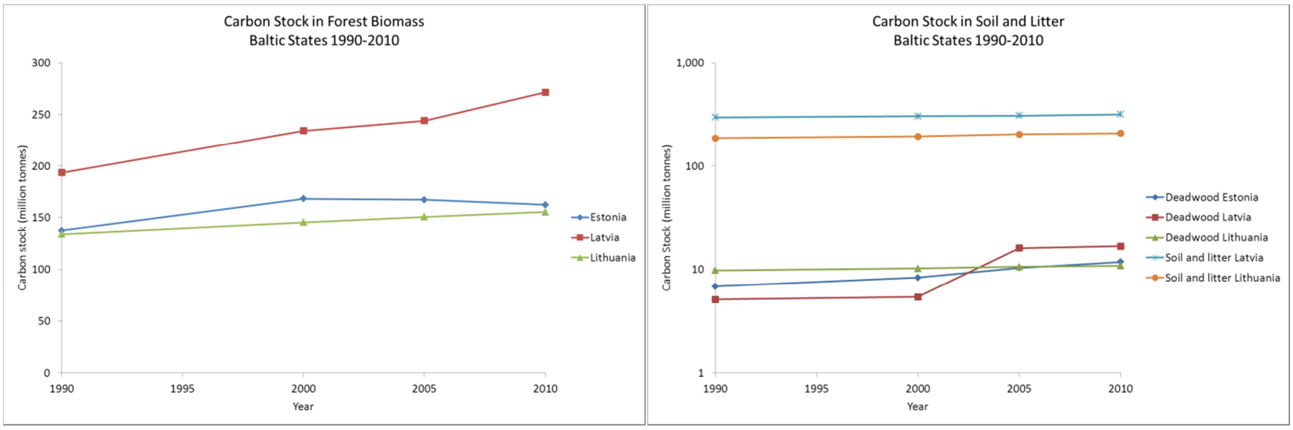


Figure 55. Carbon stock in biomass (left pane) and in dead wood and litter (right pane) in the forest in the North European region. The evolution in carbon stock in dead wood in Latvia from 2000 to 2005 suggests a change in evaluation methodology between the year 2000 evaluation and 2005. Notice the logarithmic scale on the Y-axis in the right pane. Reference: (FOREST EUROPE, UNECE et al. 2011).

11.1.2.3. Forest ownership

Baltic forests are in both public and private ownership, with public ownership ranging from 40 to 66 % and private from 34 to 46 % (Table 9).

Table 9. Ownership structure of Baltic forests (FAO 2010).

	Public	Private	Other
		%	
Estonia	40	43	17
Latvia	54	46	0
Lithuania	66	34	0

11.1.2.4. Legal and political framework

Baltic forests enjoy various levels of protection. 10-20 % of national forest areas are situated in protected area. Between 31 and 100 % of national forest areas are designated as permanent forest estate, which ensure that forests are not converted to other types of land use. A comparably large fraction of Baltic forests is covered by some level of forest management plans ensuring that forests are included in a certain level of long-term strategies (FAO 2010).

Table 10. Levels of protection of Baltic forests (FAO 2010).

	Permanent forest estate		Forest in protected area		Forest with management plan	
	1000 ha	%	1000 ha	%	1000 ha	%
Estonia	694	31	213	10	1,530	69
Latvia	1,737	52	610	18	3,354	100
Lithuania	2,160	100	433	20	2,160	100

All Baltic countries have a well-developed legal and policy framework on forests (FAO 2010). Forest policies, national forest programmes and specific forest laws are enacted in all countries. Furthermore the Baltic countries have ratified a number of supra national declarations and agreements including CBD, UNFCCC, Kyoto Protocol, CITES, Ramsar, WHC, NLBI. Latvia and Lithuania also have ratified the UNCCD.

11.1.2.5. Certification schemes

Certification schemes of sustainable forest management cover a large proportion of Baltic forests. PEFC is endorsed in Estonia and Latvia but not in Lithuania (PEFC 2012). Correspondingly FSC covers Estonia, Latvia and Lithuania (FSC 2012). At least 3.8 million ha or 49 % of the Baltic forest area is covered by one of the two major certification schemes in Europe. To what extent certified forests are certified according to only one or both schemes is not known and the total area certified is probably higher than 3.8 million ha.

Table 11. Total forest area and certified forest area in the Baltic States. Some areas may be double certified.

	Total forest area		Forest area certified by FSC		Forest area certified by PEFC	
	1000 ha	%	1000 ha	%	1000 ha	%
Estonia	2,217	52	1,106	50	898	41
Latvia	3,354	54	1,637	49	1,622	48
Lithuania	2,160	34	1,058	49	0	0

11.1.2.6. Wood and wood fuel production

The net annual increment in 2010 in Estonian and Lithuanian forests available for wood supply is estimated to 22 million m3 (FOREST EUROPE, UNECE et al. 2011). Data on forest increment is not available for Latvia. Annual felling (2010) is estimated to 14 million m^3 giving an average exploitation rate of 64 %. There are, however, national differences as Estonia had a reported exploitation in 2010 rate of 51 % and Lithuania 80 % (FOREST EUROPE, UNECE et al. 2011) Figure 56.

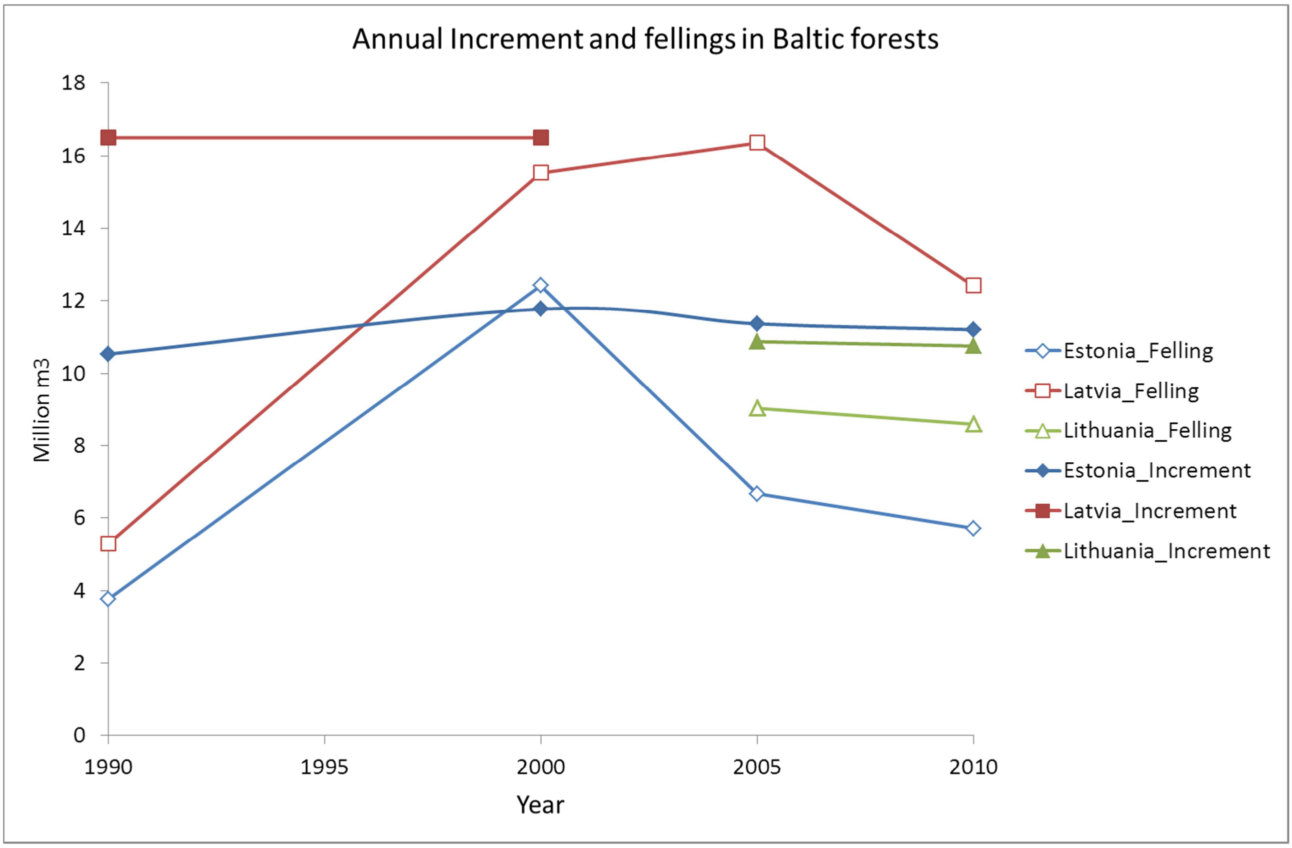


Figure 56. Annual volume increment and fellings in Baltic State forests in 1990, 2000, 2005 and 2010 respectively (FOREST EUROPE, UNECE et al. 2011).

Estonia has seen a significant reduction in production of industrial wood and wood fuel since 1990. The opposite development is seen in Latvia and Lithuania where industrial round wood production has increased 2-4 times from 1990 to 2005 (FAO 2010).

In total the Baltic States have an installed pellet production capacity of approx. 2 million tons per annum (AEBIOM 2011, AEBIOM 2012) (Figure 57). The pellet production capacity is currently utilized to 57-70 % of its capacity. Denmark is the main market for Baltic wood pellets (Cocchi, Nikolaisen et al. 2011). The origin of the resources for pellet production is not recorded, but Estonia has a large wood industry sector that could supply the pellet industry (Cocchi, Nikolaisen et al. 2011).

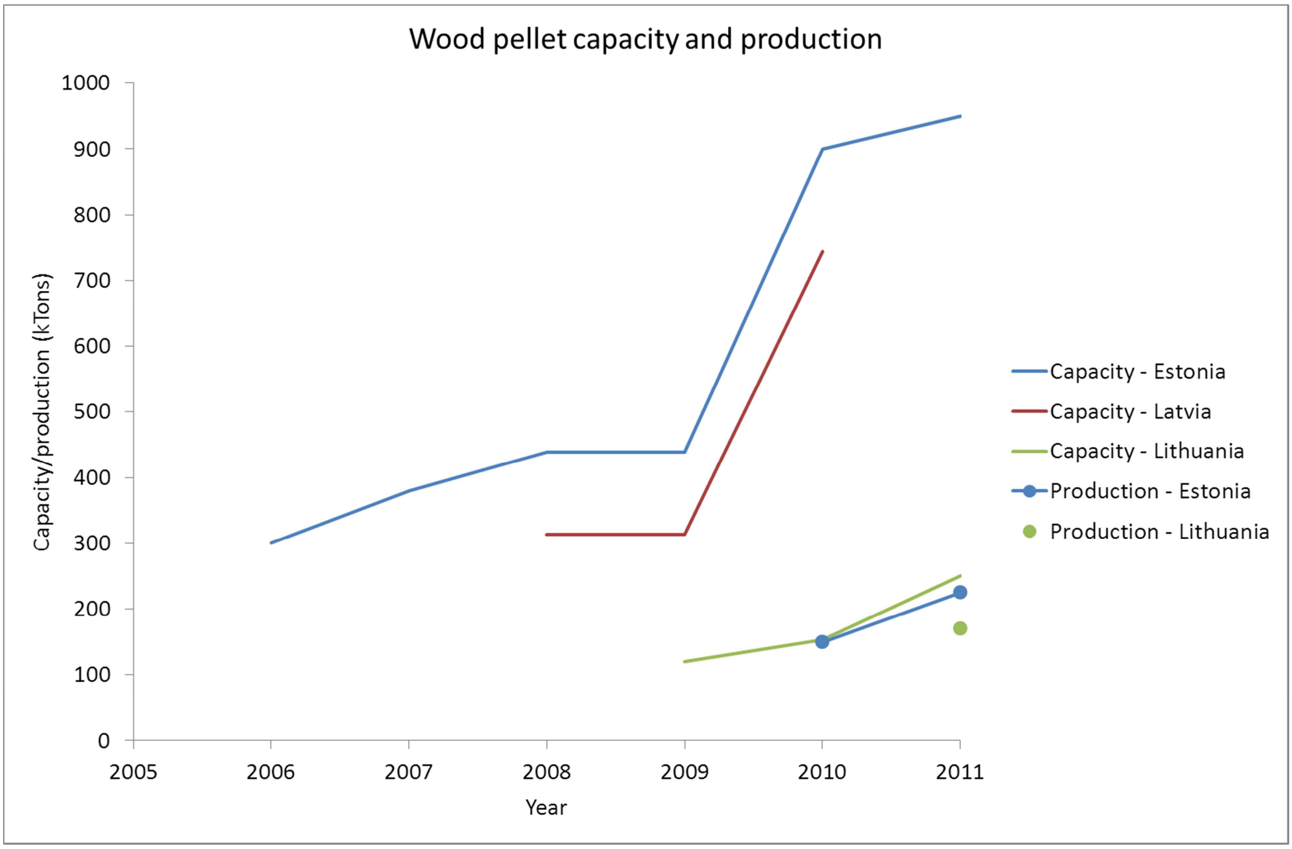


Figure 57. Wood pellet production capacity and production

The Baltic States are among the 20 largest suppliers to the Danish wood chips import, with a trend towards increased export from the Baltics to Denmark (Danmarks Statistik 2012). Estonia and Latvia are among the net exporting countries in Europe. According to (Lamers, Junginger et al. 2012) Lithuania is a net exporting country, still considerable export to Denmark is possible re-export of imported biomass.

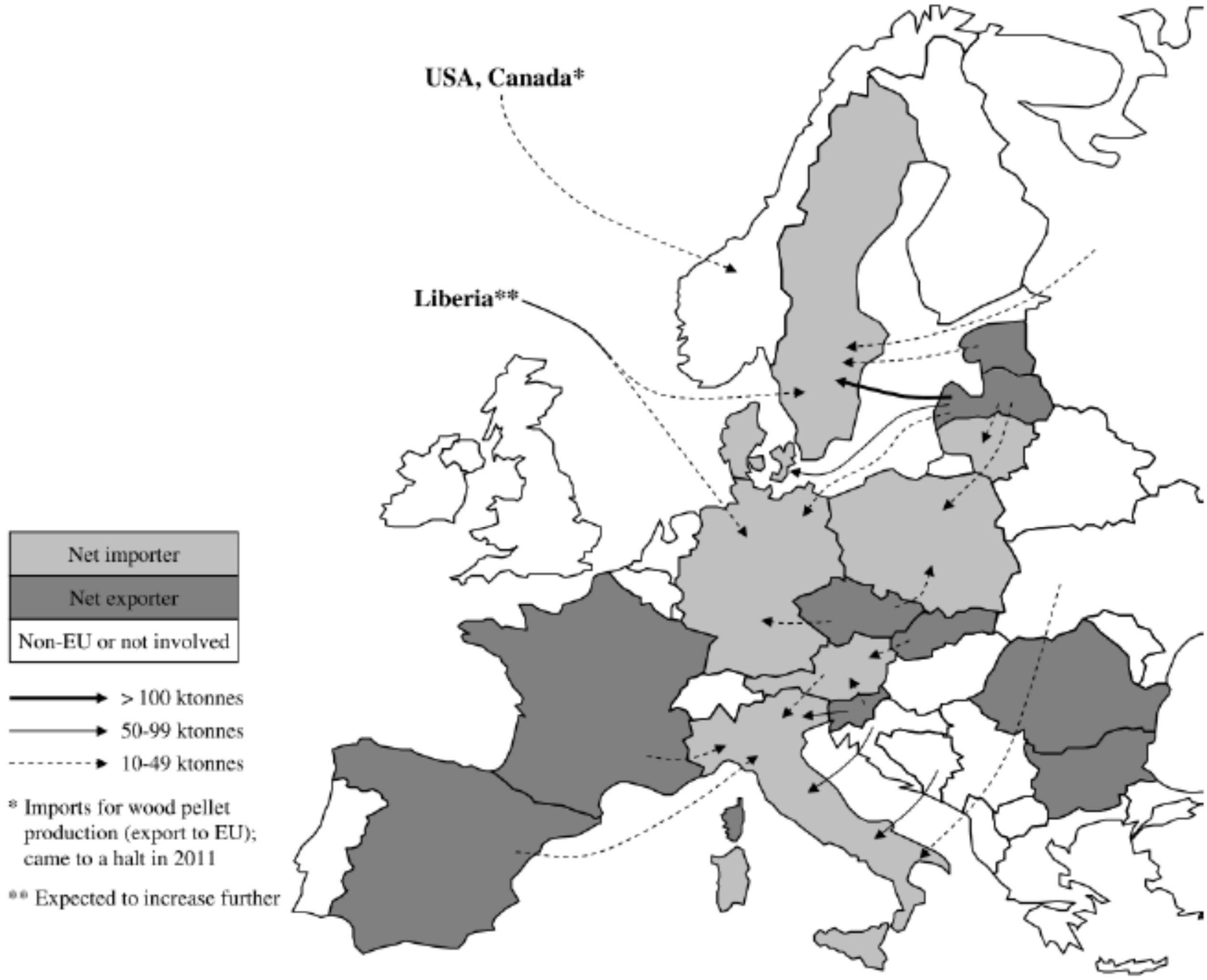


Figure 58. Patterns of wood chip trade to and from Europe. From (Lamers, Junginger et al. 2012).

11.1.2.7. Wood resource potential

(Alakangas, Heikkinen et al. 2007) estimate the amount of sawdust available against the pellet production capacity in the Baltic region. The situation in 2007 suggests that only Lithuania has secondary residue resource surplus to build up further capacity. These numbers does not, in themselves indicate resource shortages as the production capacity currently isn't fully utilized (Cocchi, Nikolaisen et al. 2011), however, particularly in Estonia and Latvia the pellet production capacity has increased since 2007 (Figure 57).

The amount of woody biomass resources in the Baltic States sums up to somewhere between 50 and 160 PJ depending on which resource fractions are included (Table 8). The review of resource assessment suggests that Latvia has the most un-used biomass resources.

Table 12. Overview of recent estimates of woody biomass resources in the Baltic States.

	Resource	Potential	Period	Unit	Estonia	Latvia	Lithuania	Total
(European Environment Agency 2006)	Forestry resources	Environmentally-compatible	2020	PJ	8	25	25	58
			2030	PJ	8	25	17	50
(Ericsson and Nilsson 2006)	Wood industry by-products	Technical	2010-20	PJ	~10	~15	~35	~60
	Forest residues	Technical	2010-20		<10	<10	<10	
(Böttcher, Dees et al. 2010)	Stemwood, branches, stumps, secondary residues	Technical	2005-10	PJ	59	57	43	159
	Aboveground residues	Technical		PJ	19	34	18	71
(Alakangas, Heikkinen et al. 2007)	Forest residues, industrial by-products	Techno-economic	2004	PJ	~12	~70		
(Hetsch 2009)	Stemwood, forest residues, stumps, woody biomass outside forest, forest expansion, industry residue and post-consumer waste	Additional socio-economic supply potential	2020	Mm^3	3.0	4.0	2.4	9.4

11.1.3. Western Europe

11.1.3.1. Forest types

Western Europe comprises Austria, Belgium, France, Germany, the Netherlands, and Switzerland. The region is to a large extent dominated by temperate broadleaf and mixed forests. Temperate coniferous forests are found in mountainous areas (FOREST EUROPE, UNECE et al. 2011).

The total forest area in the region is 33 million ha corresponding to an average forest cover of 30 %. Forest cover in individual countries varies between 11 % (the Netherlands) and 47 % in Austria (FAO 2010).

Very little primary forest is left in Western Europe. Approx. 70,000 ha is characterised as such. 21 million ha is naturally regenerated and 8 million ha is planted. Data does not include Austria (FAO 2010).

Western Europe follows the general trend of Europe with increasing forest area. Since 1990 the forest area is extended with 2 million ha. The increase takes place particularly in France (FAO 2010).

11.1.3.2. Carbon

For the Western European region and reservoirs in total the amount of carbon stored has increased from 3.9 billion tonnes in 1990 to 4.8 billion tonnes in 2010. Data for France on carbon in dead wood and for Austria and Germany on carbon in soil and litter are not available (FOREST EUROPE, UNECE et al. 2011). Particularly Franc and Germany exhibit a considerable increase in carbon stored in living forest biomass.

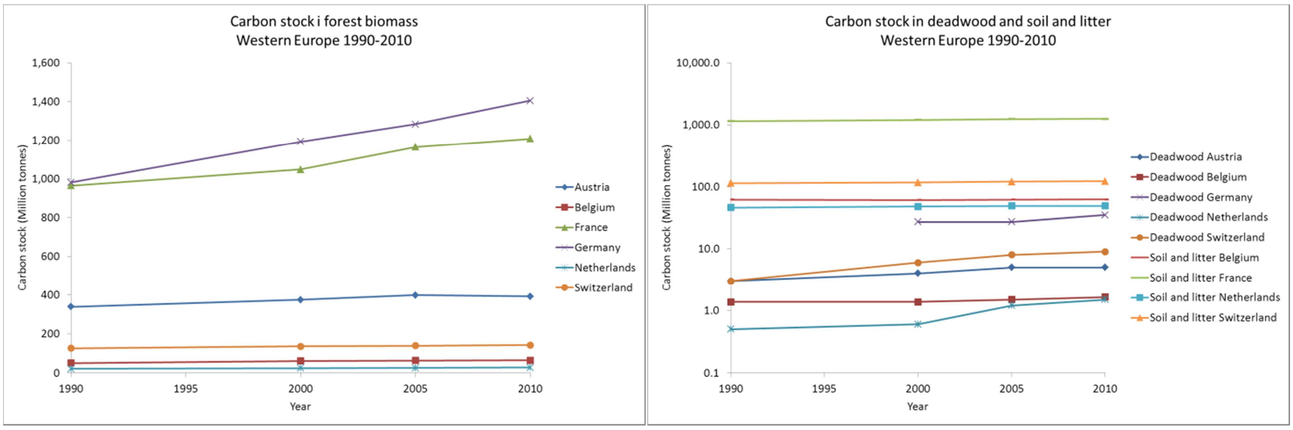


Figure 59. Carbon stock in forest biomass, dead wood and forest soil and litter in Western Europe. Data for carbon in soil and litter in Austria is missing (FOREST EUROPE, UNECE et al. 2011).

11.1.3.3. Ownership

The ownership structure of Western European forest is mixed but both private and public ownerships is common in all countries.

Table 13. Ownership structure of Western European forests (FAO 2010).

	Public	Private	Other
		%	
Austria	19	81	0
Belgium	44	56	0
France	26	74	0
Germany	53	44	4
Netherlands	49	51	0
Switzerland	68	32	0

11.1.3.4. Legal and political framework

In most of the countries all or most of the forest area is characterised as permanent forest estate. An exception is the Netherlands where practically nothing is characterised as permanent forest. 43 to 68 % of the forest area in individual countries is covered by management plans.

Table 14. Levels of protection of Western European forests (FAO 2010).

	Permanent forest estate		Forest in protected area		Forest with management plan	
	1000 ha	%	1000 ha	%	1000 ha	%
Austria	3,887	100	659	17	1,944	50
Belgium			209	31	360	53
France	15,954	100	313	2	6,826	43
Germany	10,568	95	2,754	25	7,528	68
Netherlands	3	1	83	23	226	62
Switzerland	1,240	100	90	7	618	50

All Western European countries have ratified the supra national declarations and agreements CBD, UNFCCC, Kyoto Protocol, UNCCD, ITTA, CITES, Ramsar, WHC, and NLBI (FAO 2010).

11.1.3.5. Certification

The level of certification in Western Europe is variable, but in general PEFC certification has a larger penetration than FSC certification.

Table 15. Total forest area and certified forest area in Western Europe (FSC 2012, PEFC 2012). Some areas may be double certified.

	Total forest area		Forest area certified by FSC		Forest area certified by PEFC	
	1000 ha	%	1000 ha	%	1000 ha	%
Austria	3,887	47	427	11	2,638	68
Belgium	678	22	20	3	289	43
France	15,954	29	15	0.1	7,847	49
Germany	11,076	32	544	5	7,394	67
Netherlands	365	11	171	47	0	0
Switzerland	1,240	31	613	49	206	17

11.1.3.6. Wood and wood fuel production

From 1990 to 2005 the region experienced increased production of industrial round wood and wood fuel. Industrial round wood production increased from 94 Mm3 in 1990 over 106 Mm3 in 2000 to 117 Mm3 in 2005. In 2010 the production dropped to almost year 1990 level; 97 Mm3. Almost same development is seen for fuel wood. 49 Mm^3 in 1990 and 2000, 52 Mm^3 in 2005 and 43 Mm^3 in 2010 (FAO 2010, FAO 2012).

In total net annual increment in 2010 in forests available for wood supply is estimated to 235 million m^3 (FOREST EUROPE, UNECE et al. 2011) (Figure 60). Increment has decreased slightly since 1990. Annual felling (2010) in total is estimated to 155 million m^3.

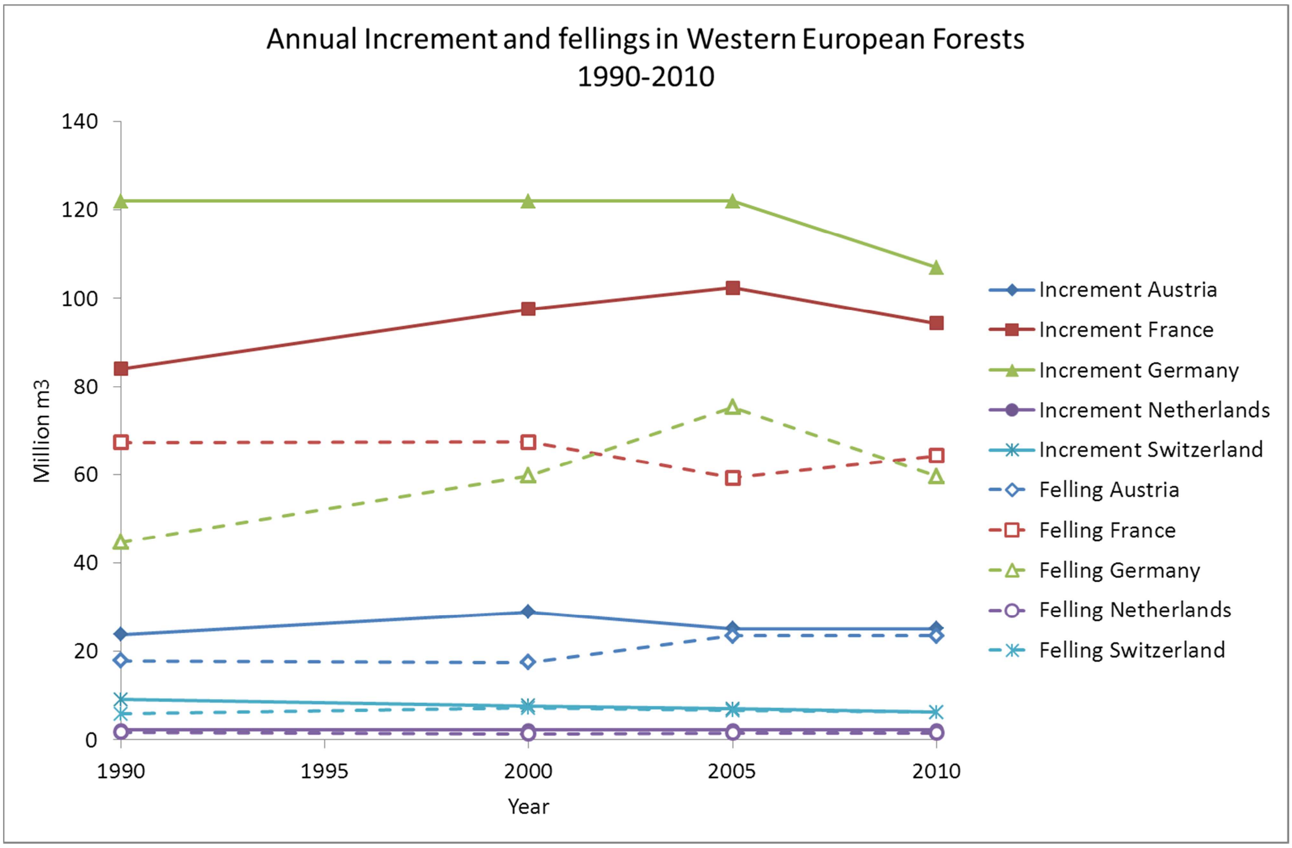


Figure 60. Annual volume increment and fellings in Western European forests in 1990, 2000, 2005 and 2010 respectively. Data are not available for Belgium (FOREST EUROPE, UNECE et al. 2011).

There is an overall trend towards increased exploitation of the forest resource. Austria, Germany and Switzerland exhibit higher rates in 2010 than in 1990. In France and the Netherlands the exploitation rates have declined (FOREST EUROPE, UNECE et al. 2011).

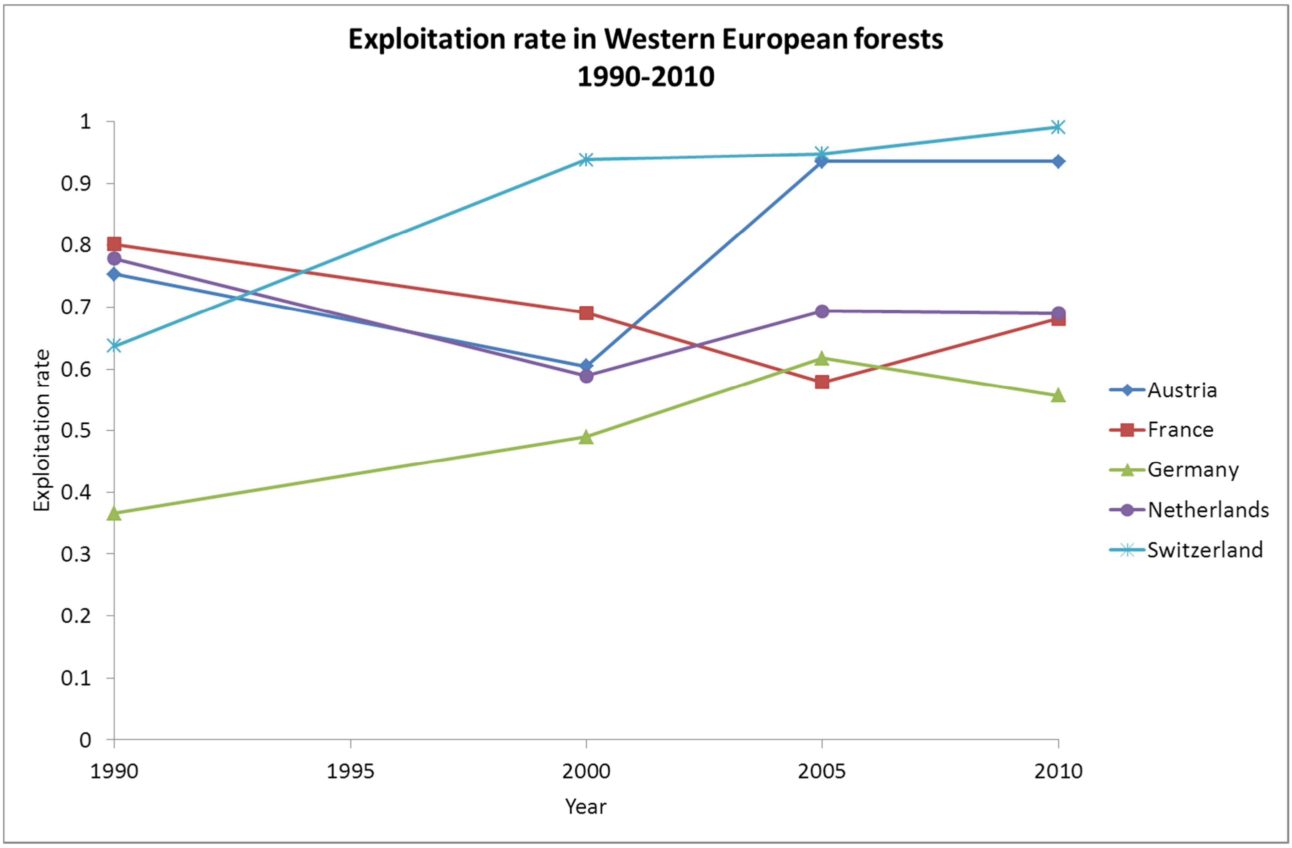


Figure 61. Forest exploitation rates in Western European forest 1990 to 2010. Data are not available for Belgium (FOREST EUROPE, UNECE et al. 2011).

Pellet production in the Western European countries is primarily based on wood industry residues (Cocchi, Nikolaisen et al. 2011). Austria has a pellet production capacity of 1.25 million tons, with a production in 2011 of 0.94 million tons. The feed stock is not reported, but Austria does have a large wood industry, potentially capable of providing residues for pellet production if the resource isn't used elsewhere. Belgium has a production capacity of ~0.5 million tons and a production of ~0.3 million tons. Most of the capacity is located in the southern part of the country (Wallonia) as the forest cover is larger than in the northern part (Flanders). AEBIOM (AEBIOM 2011, AEBIOM 2012) report that Germany has Europe's largest pellet production capacity of 2.7 million tons and production of 1.8 million tons in 2011. Pellet production is based 70 % on sawmill residues and 30 % on low grade round wood/pulp wood. Currently the French production relies on wood industry residues, but a shift towards forest residues and round wood as feedstock is expected. The production in 2010 was 0.46 million tons out of a capacity of ~1 million tons (Cocchi, Nikolaisen et al. 2011). Also the Dutch production is based on industry residues. Feedstock potentials are limited as the wood industry isn't well developed in the country, so the potential for a significant growth in pellet production is limited, which is reflected in the development in capacity since 2005 (Figure 62). Particularly in Germany the pellet production capacity has grown from 2005 to 08.

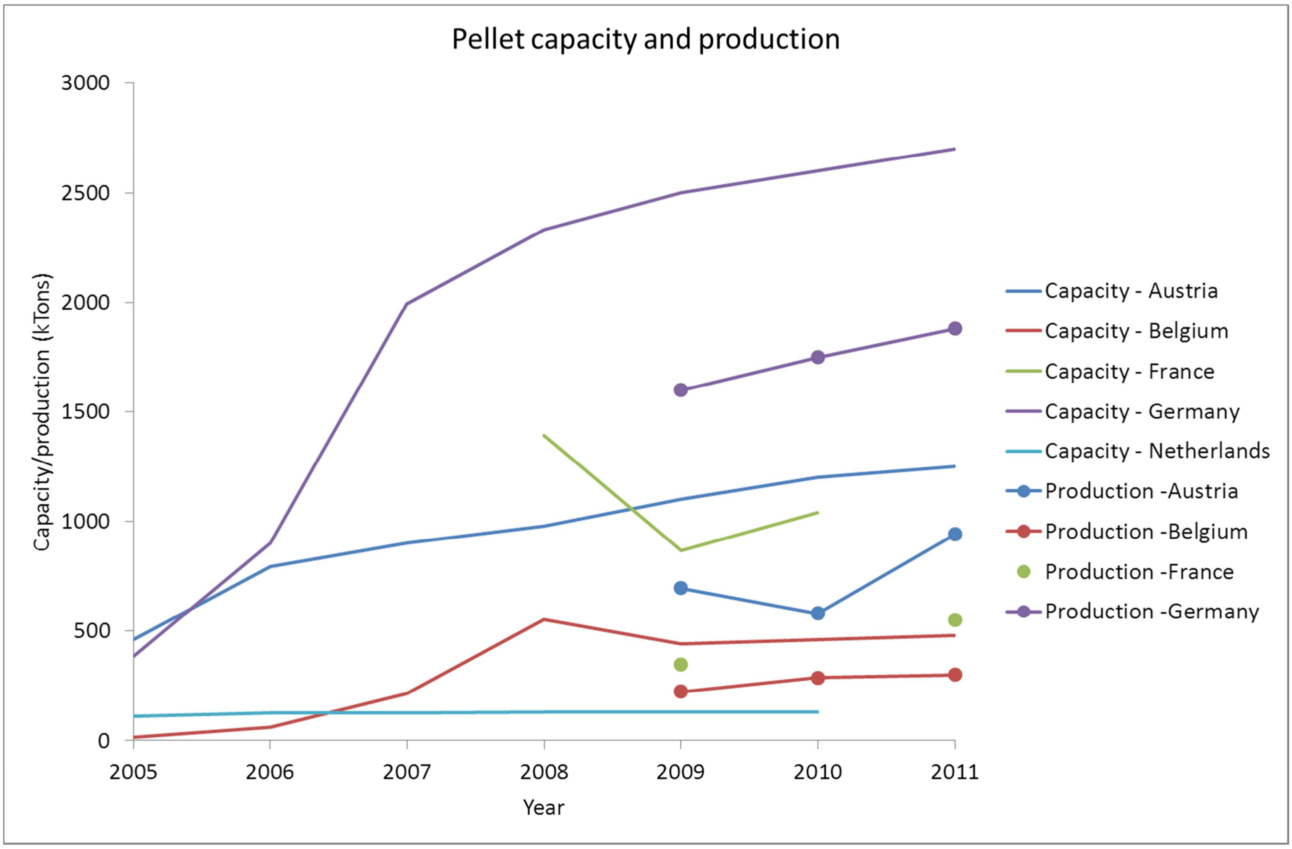


Figure 62. Pellet production capacity and pellet production in the Western European region. Based on data from (AEBIOM 2011, AEBIOM 2012).

11.1.3.7. Wood resource potential

In terms of resource potentials France and Germany are the main countries, but also Austria hold large amounts of woody biomass. According to the assessment by (Hetsch 2009) particularly France and Germany holds a certain amount of unused resource in comparison to the other countries in the region (Table 16).

Table 16. Overview of recent assessments of wood resources for energy purposes in the Western European countries.

	Resource	Potential	Period	Unit	Austria	Belgium	France	Germany	Netherlands	Switzerland
(European Environment Agency 2006)	Forestry resources	Environmentally-compatible	2020	PJ	138	4	553	222	4	
			2030	PJ	147	8	595	201	8	
(Ericsson and Nilsson 2006)	Wood industry by-products	Technical	2010-20	PJ	~60	<10	~170	~160	<10	
	Forest residues	Technical	2010-20		~30	<10	~80	~90	<10	
(Böttcher, Dees et al. 2010)	Stem wood, branches, stumps, secondary residues	Technical	2005-10	PJ	156	26	644	566	11	
	Aboveground residues	Technical		PJ	67	18	188	241	3	
(Alakangas, Heikkinen et al. 2007)	Forest residues, industrial by-products	Techno-economic	2004	PJ	~16	<10		~214	<10	
(Hetsch 2009)	Stem wood, forest residues, stumps, woody biomass outside forest, forest expansion, industry residue and post-consumer waste	Additional socio-economic supply potential	2020	Mm^3	5.9	1.9	36.3	29.1	1.2	2.9

11.1.4. Eastern Europe excl. Russia

11.1.4.1. Forest types

The Eastern European region includes Belarus, Bulgaria, Czech Republic, Hungary, Moldova, Poland, Romania, Slovakia and Ukraine. Most of the area is characterised as temperate broadleaf and mixed forest, with temperate coniferous biomes in the mountainous areas (UNEP, FAO et al. 2009). The forest area has steadily increased from 42.3 million ha in 1990 to 45.2 million ha in 2010. The increase in forest area is distributed across most countries in the region. In Slovakia the forest area has remained practically constant.

11.1.4.2. Carbon

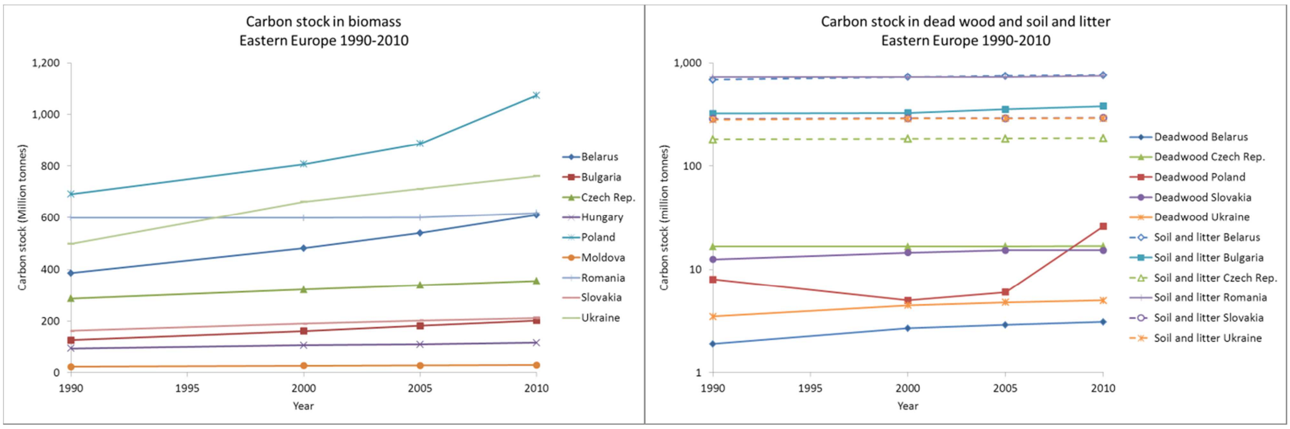


Figure 63. Development in carbon stock in biomass (left pane) and in dead wood, soil and litter (right pane) in eastern European forests from 1990 to 2010. Notice the logarithmic scale on the graph in the right pane (FOREST EUROPE, UNECE et al. 2011).

11.1.4.3. Forest ownership

In contrast to Northern and Western Europe the Eastern European forests area is to a much greater extent publicly owned. Between 52 and 100 % is in public ownership.

Table 17. Ownership pattern in Eastern European forests.

	Public	Private	Other
	%	%	%
Belarus	100	0	0
Bulgaria	89	11	0
Czech Republic	76	24	0
Hungary	58	42	n.s.
Moldova	100	n.s.	0
Poland	83	17	0
Romania	80	20	0
Slovakia	52	43	6
Ukraine	100	n.s.	0

11.1.4.4. Legal and political framework

In contrast to other European Regions the forests in the Eastern European region is to a large extent covered by management plans. 100 % of the forests, for which there are data are characterised as permanent forest estates (FAO 2010). Management plans also cover the majority of forests.

Table 18. Levels of protection of Eastern European forests (FAO 2010).

	Permanent forest estate		Forest in protected area		Forest with management plan	
	1000 ha	%	1000 ha	%	1000 ha	%
Belarus	8,630	100	1,208	14	8,630	100
Bulgaria	3,927	100	313	8	3,927	100
Czech Rep.	2,657	100	740	28	2,657	100
Hungary	2,029	100	424	21	2,029	100
Moldova	-	-	64	17	-	-
Poland	9,337	100	187	2	8,382	90
Romania	6,573	100	1,746	27	5,210	79
Slovakia	1,933	100	1,104	57	1,933	100
Ukraine	9,705	100	-	-	8,900	92

All countries in the regions have ratified the CBD, UNFCCC, Kyoto Protocol, UNCCD, CITES, Ramsar, WHC, and NLBI (FAO 2010). Poland has further ratified the ITTA.

11.1.4.5. Certification

Table 19.Total forest area and certified forest area in Eastern Europe (FSC 2012, PEFC 2012). Some areas may be double certified.

	Total forest area		Forest area certified by FSC		Forest area certified by PEFC	
	1000 ha	%	1000 ha	%	1000 ha	%
Belarus	8,630	42	5,395	63	7,704	89
Bulgaria	3,927	36	218	6	0	0
Czech Rep.	2,657	34	50	2	1,845	69
Hungary	2,029	23	310	15	0	0
Moldova	386	12	0	0	0	0
Poland	9,337	30	6,985	75	6,283	67
Romania	6,573	29	717	11	0	0
Slovakia	1,933	40	144	7	1,240	64
Ukraine	9,705	17	1,455	15	0	0

11.1.4.6. *Wood and wood fuel production*

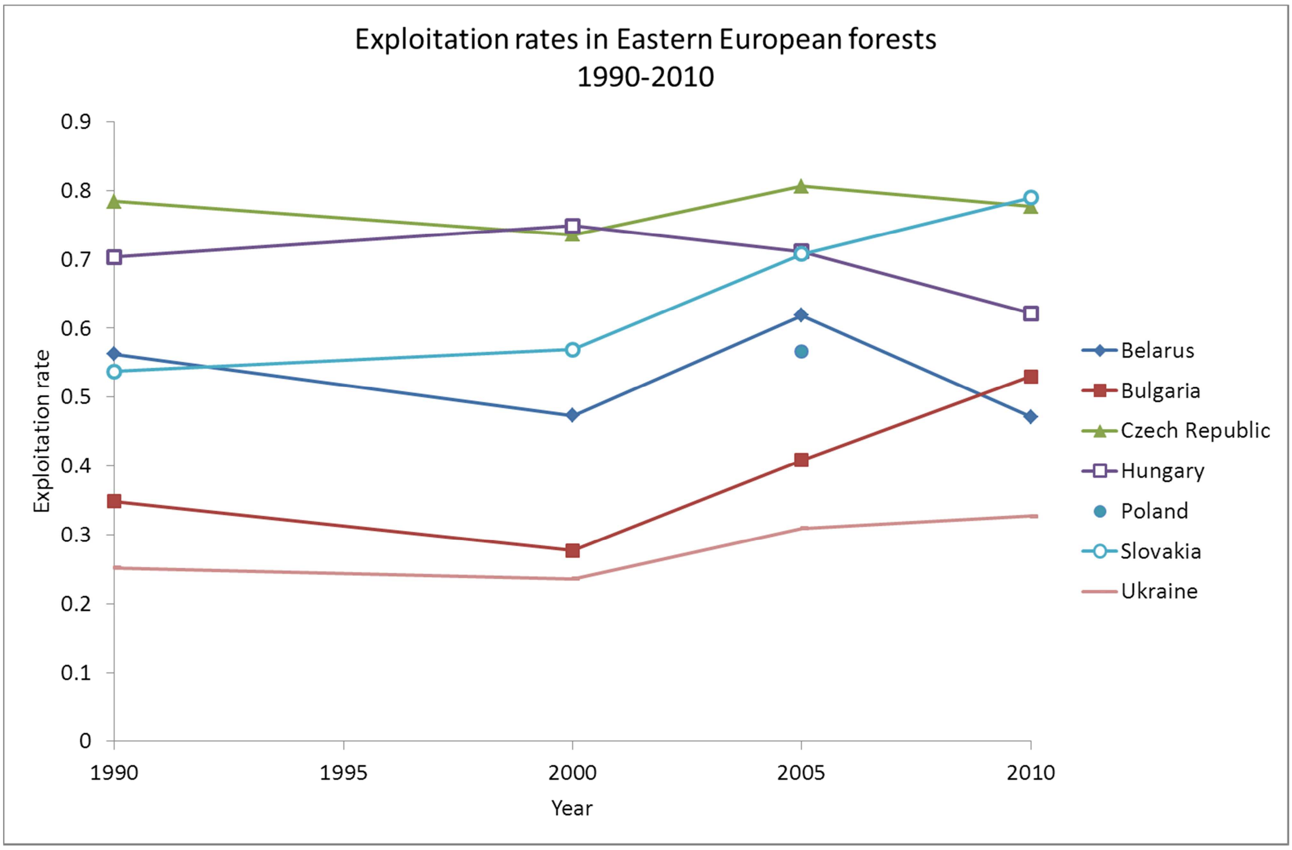


Figure 64. Exploitation rates in the forests in the Eastern European regions in 1990, 2000, 2005 and 2010 (FOREST EUROPE, UNECE et al. 2011).

Information on the Eastern European pellet industry is somewhat more limited than for Western and Northern Europe and information sources are more diverging. (Cocchi, Nikolaisen et al. 2011) report Poland to have a production capacity of 0.9 million tons and a production of 0.66 million tons in 2010. The AEBIOM statistics report a lower capacity of 0.64 million tons (*Table 20*). In Hungary the production capacity grows fast, but is still comparatively small with 160,000-200,000 tons in 2010 and a production of 134,000-162,000 tons. Ukraine has a large pellet production capacity, but most of it is targeted towards agro pellets. Wood pellets make up less than 15 % of the total, with a production in 2010 of 95,000 tons. Pellet production in the Czech Republic production is based on spruce and pine sawdust (Cocchi, Nikolaisen et al. 2011).

Table 20. Pellet production capacity and production in East European countries 2005-2011. Based on statistical data from (AEBIOM 2011, AEBIOM 2012).

		2005	2006	2007	2008	2009	2010	2011
Bulgaria	Capacity			23	62	62	70	
	Production							
Czech Rep.	Capacity			118	258	258	300	
	Production					160	145	137
Hungary	Capacity				110	125	200	
	Production					81	162	
Poland	Capacity	300	416	545	644	644	640	
	Production							
Romania	Capacity			214	241	241	260	
	Production							
Slovakia	Capacity		87		142	142	142	
	Production							

11.1.4.7. Wood resource potentials

Recent estimates of biomass potentials of logging residues or wood industry residues are presented in Table 21. Particularly Poland and Romania appear to have comparably large resources of both forest and industry residues.

Table 21. Overview of recent assessments of woody biomass resources in Eastern European countries.

	Resource	Potential	Period	Unit	Belarus	Bulgaria	Czech rep.	Hungary	Poland	Romania	Slovakia	Ukraine
(European Environment Agency 2006)	Forestry resources	Environmentally-compatible	2020	PJ			33	8	63		38	
			2030	PJ			38	17	50		38	
(Böttcher, Dees et al. 2010)	Stemwood, branches, stumps, secondary residues	Technical	2005-10	PJ		83	69	88	302	207	41	
	Aboveground residues	Technical		PJ		33	50	20	133	64	31	
(Hetsch 2009)	Stemwood, forest residues, stumps, woody biomass outside forest, forest expansion, industry residue and post-consumer waste	Additional socio-economic supply potential	2020	Mm^3	1.9	3.3	4.0	3.7	0.2	20.4	10.8	4.1
(Cocchi, Nikolaisen et al. 2011	Wood industry residues	Technical		PJ					58			26-28

11.1.5. Southern Europe

11.1.5.1. Forest types

The southern European region includes Albania, Bosnia and Herzegovina, Croatia, Greece, Italy, Malta, Montenegro, Portugal, Serbia, Slovenia, Spain, and Macedonia. The region is characterised by temperate broadleaved and mixed forests towards the north and east of the region and Mediterranean forests and scrublands round the Mediterranean Sea.

The total forest area in the region has increased from 37.8 million ha in 1990 to 45.1 million ha in 2010. Forest expansion has taken place particularly in Spain, Italy, Greece and Serbia. Only Albania and Bosnia and Herzegovina has experience minor reductions in the area covered by forest.

11.1.5.2. Carbon

The rate of exploitation shows in the development in carbon storages in living biomass in the forests, which for all countries are constant or increasing (Figure 65). This development is a function of partly increased forest area and potentially also higher stocking per ha. Data on stocking is only available for a few countries in southern Europe, but they indicate an increasing stocking from 1990-2010.

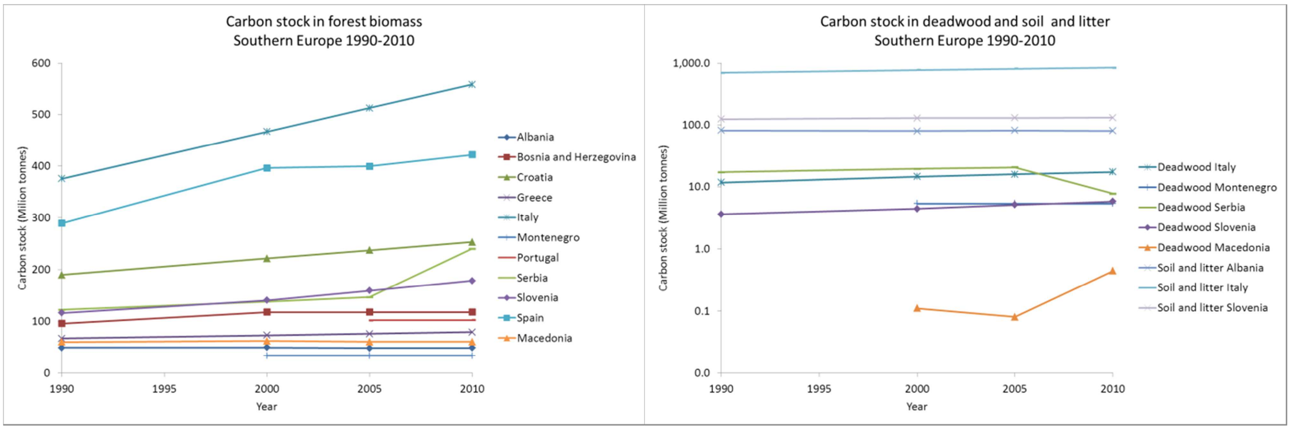


Figure 65. Carbon stores in living forest biomass and dead wood and soil in southern European forests 1990-2010.

11.1.5.3. Forest ownership

Forest ownership patterns diverge across the Southern European countries from practically all forests in public ownership to practically all privately owned. There is a tendency of a higher proportion of public ownership in former Warsaw pact countries.

Table 22. Ownership structure of Southern European forests (FAO 2010).

	Public	Private	Other
	%	%	%
Albania	98	2	0
Bosnia and Herzegovina	79	21	0
Croatia	73	27	0
Greece	77	23	0
Italy	34	66	0
Macedonia	90	10	0
Malta	100	0	0
Montenegro	67	33	0
Portugal	2	98	0
Serbia	51	49	0
Slovenia	26	74	0
Spain	29	66	5

11.1.5.4. Legal and political framework

Table 23. Levels of protection of South European forests (FAO 2010).

	Permanent forest estate		Forest within protected area		Forest with management plan	
	1000 ha	%	1000 ha	%	1000 ha	%
Albania	776	100	162	21	776	100
Bosnia and Herzegovina	-	-	-	-	-	-
Croatia	1920	100	54	3	1489	78
Greece	-	-	164	4	-	-
Italy	9030	99	3265	36	-	-
Macedonia	918	92	-	-	918	92
Malta	-	-		100		100
Montenegro	-	-	13	2	-	-
Portugal	1281	37	700	20	1081	31
Serbia	2713	100	452	17	2252	83
Slovenia	-	-	241	19	1253	100
Spain	18173	100	2499	14	3487	19

11.1.5.5. Certification

Most countries in the south European region have a low degree of forest certification, with Bosnia and Herzegovina, Serbia and Slovenia being exceptions. All three countries have comparably small forest areas.

Table 24. Total forest area and certified forest area in Eastern Europe (FSC 2012, PEFC 2012). Some areas may be double certified.

	Total forest area		Forest area certified by FSC		Forest area certified by PEFC	
	1000 ha	%	1000 ha	%	1000 ha	%
Albania	776	28	0	0	0	0
Bosnia and Herzegovina	2,185	43	1,006	46	0	0
Croatia	1,920	34	2,029	-	0	0
Greece	3,903	30	0	0	0	0
Italy	9,149	31	52	0.6	774	8
Macedonia	998	39	0	0	0	0
Malta	-	1	0	0	0	0
Montenegro	543	40	0	0	0	0
Portugal	3,456	38	315	9	219	6
Serbia	2,713	31	1,037	38	0	0
Slovenia	1,253	62	259	21	0	0
Spain	18,173	36	159	0.9	1,530	8

11.1.5.6. Wood and wood fuel production

Wood production in southern Europe as a whole has been fairly constant over the last 20 years. From 1990 to 2005 the production of industrial wood has been in the range 40-42 million m^3 annually and wood fuel production 14-16 million m^3. As such 70-75 % of forest production is aimed at wood industrial purposes.

Comparable data on wood production and forest increment is available only for a limited number of countries in southern Europe (Figure 66). Calculated exploitation rates lies in most cases between 40 % and 60 %, with the exception of Portugal, where the exploitation of forest increment is higher at 70-80 %.

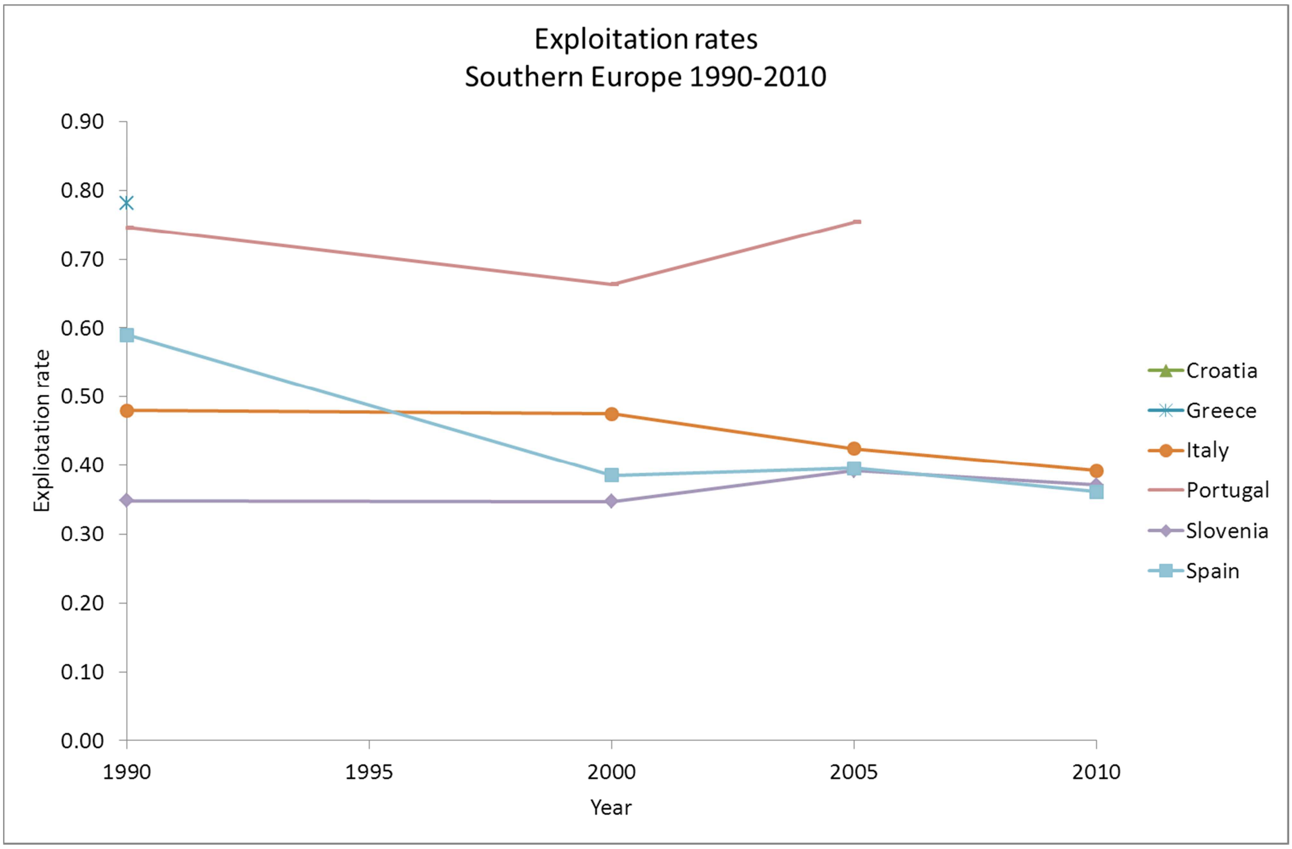


Figure 66. Exploitation rates in southern European Forests 1990-2010 (FAO 2010).

Data on pellet production and capacity for Southern European countries is scarce. AEBIOM has collected production and capacity data from various sources (Figure 69). Italy, Portugal and Spain have the largest capacity, each with approx. 7-800,000 tons annually in 2011. In Portugal production has increased significantly from 2009 to 2011, from 400,000 to 650,000 tons, while the capacity has remained more or less constant.

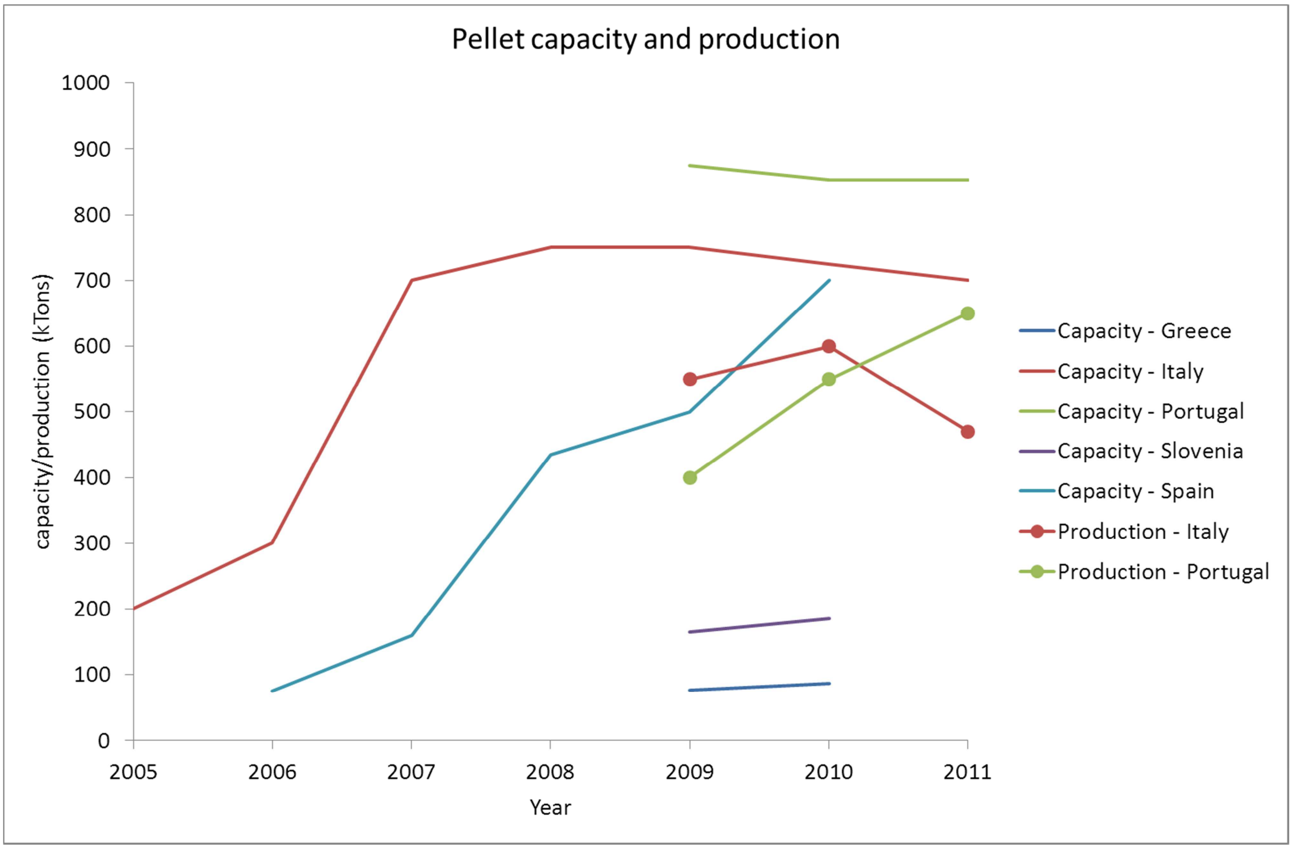


Figure 67. Pellet production capacity and pellet production in southern Europe 2005-2011 (AEBIOM 2011, AEBIOM 2012).

11.1.5.7. Wood resource potential

The number of assessments covering the southern European region is limited, but a number of assessments do cover the European Union member states (Table 25). According to the assessments particularly Italy and Spain have large resources at their disposal and to a lesser extent also Portugal and Slovenia.

Table 25. Overview of recent assessments of woody biomass potentials in southern European forests.

	Resource	Potential	Period	Unit	Albania	Bosnia and Herzegovina	Croatia	Greece	Italy	Montenegro	Portugal	Serbia	Slovenia	Spain	Macedonia
(European Environment Agency 2006)	Forestry resources	Environmentally-compatible	2020	PJ				-	138		8		46	75	
			2030	PJ				-	126		8		42	63	
(Böttcher, Dees et al. 2010)	Stemwood, branches, stumps, secondary residues	Technical	2005-10	PJ				30	331		44		42	171	
	Aboveground residues	Technical		PJ				9	51		35		11	78	
(Hetsch 2009)	Stemwood, forest residues, stumps, woody biomass outside forest, forest expansion, industry residue and post-consumer waste	Additional socio-economic supply potential	2020	Mm^3	-1.2	0	1.7	4.4	20.4	0.3	4.1	1.1	1.8	25.5	0.011

11.1.6. Russia

11.1.6.1. Forest types

Russia plays a unique role in the evaluation of European forest as Russia alone has close to 4 times more forest that the rest of Europe combined. Russia is dominated by the boreal zone in the north. In the South-Western part the temperate broadleaf and mixed forest zone is predominant. The southern part of Russia is to great extent characterised by savannah and scrubland with parts being characterised by temperate coniferous forests, particularly in mountainous regions.

Forest covers 809 million ha corresponding to 49 % of the total land area. The forest area has remained practically constant from 1990. More than 130 million ha is considered unavailable for wood supply, however, still leaving 677 million ha available for wood supply (FOREST EUROPE, UNECE et al. 2011).

In 2010 256 million ha (32 %) was classified as primary forest, 536 million ha (66 %) as naturally regenerated forest and 17 million ha (2 %) as planted forest.

11.1.6.2. Carbon

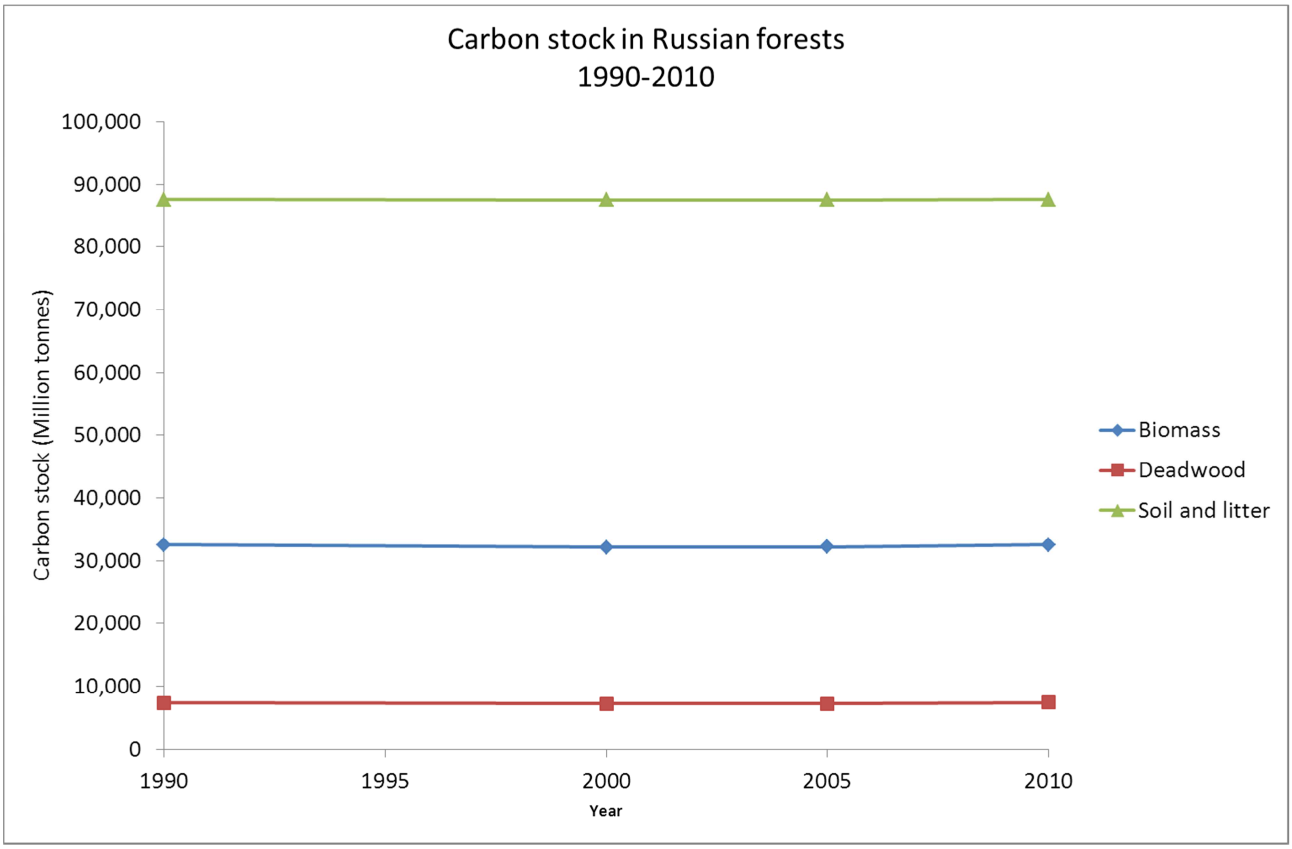


Figure 68. Development in carbon stock in Russian forests 1990 to 2010.

11.1.6.3. Forest ownership

As of 2005 private ownership was non-existent in Russia. 100 % of the forest area is publicly owned.

11.1.6.4. Legal and political framework

Probably due to the ownership structure of Russian forest 100 % of the forest area is under some sort of management plan. Other protection parameters have comparably low penetration, with 2 % of the forest in protected area and 22 % of the forest designated as permanent forest estate.

Table 26. Levels of protection of Russian forests (FAO 2010).

	Permanent forest estate		Forest in protected area		Forest with management plan	
	1000 ha	%	1000 ha	%	1000 ha	%
Russia	108,697	22	17,572	2	809,090	100

Russia has a national forest programme from 2003 and a specific forest law from 2006, but no national forest policy. Russia has ratified the CBD, UNFCCC, Kyoto Protocol, UNCCD, CITES, Ramsar, WHC, and NLBI.

11.1.6.5. Certification

Forest certification schemes are not commonly applied in Russia.

Table 27. Total forest area and certified forest area in Russia (FSC 2012, PEFC 2012). Some areas may be double certified.

	Total forest area		Forest area certified by FSC		Forest area certified by PEFC	
	1000 ha	%	1000 ha	%	1000 ha	%
Russia	809,090	49	33,091	4	644	-

11.1.6.6. Wood and wood fuel production

Industrial wood production declined dramatically from 1990 to 2000, possibly due to the economic and political breakdown of the former Soviet Union countries. In 1990 the production was 258 million m^3, which was reduced to 105 million m^3 in 2000. In 2005 industrial wood production had increased to 135 million m^3.

Wood fuel production shows a similar pattern, although not to the same extent as industrial wood; 68 million m3 in 1990, 48 million m3 in 2000 and 51 million m3 in 2005.

The net annual increment in 2010 of Russian forests available for wood supply is estimated to 853 million m^3 (FOREST EUROPE, UNECE et al. 2011). With an annual felling (2010) of 170 million m3 Russia is the country in Europe with the lowest felling rate of 19.9 %. Average felling rate for Europe without Russia is 62.4 % and the EU27 64.2 %.

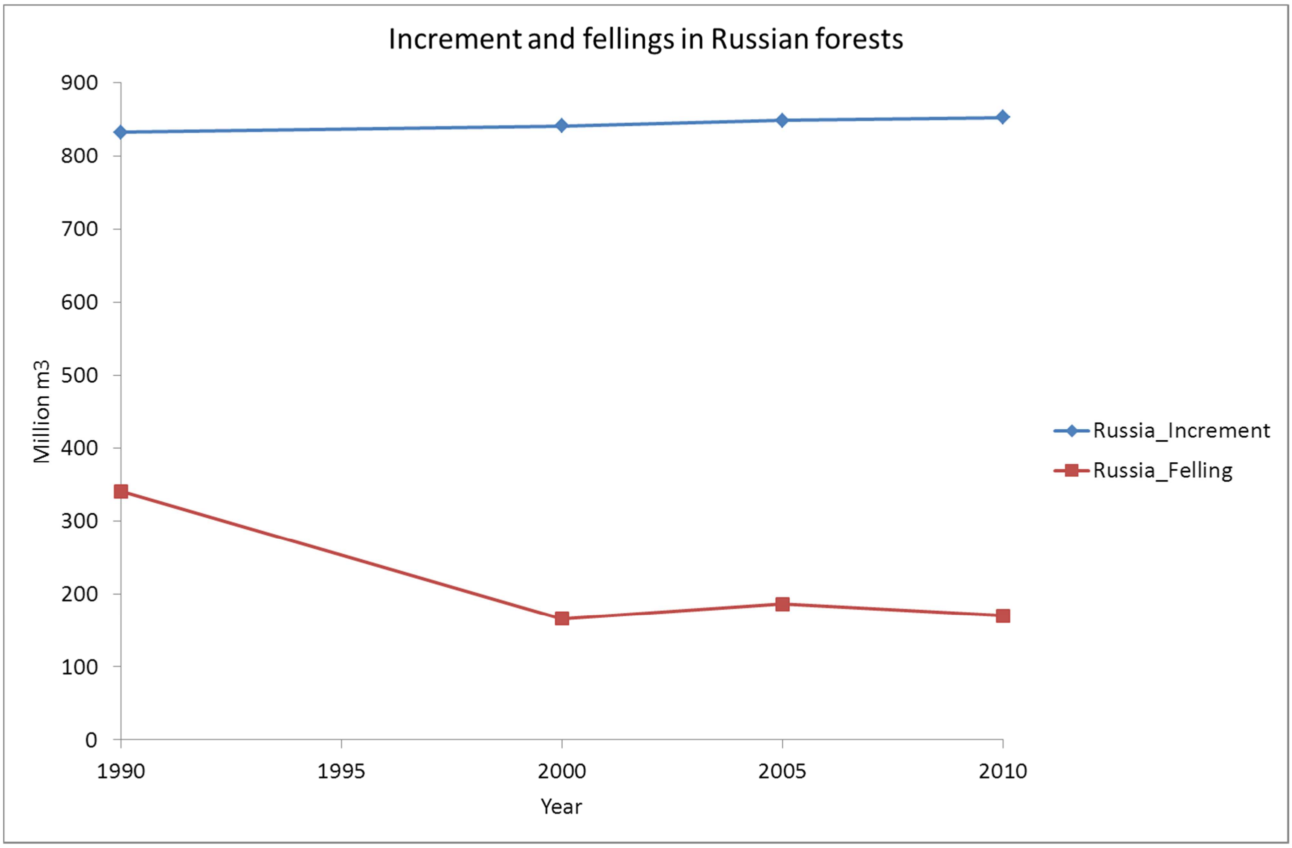


Figure 69. Felling and increment in Russian forests from 1990 to 2010.

The Russian pellet production capacity in 2010 is estimated to 2-3 million tonnes annually (Cocchi, Nikolaisen et al. 2011). A majority of the capacity is located in the North-West Federal District. Capacity utilisation is about 50 %. In 2009 900,000 tonnes wood pellets was produced in Russia of which 500-600,000 tonnes was exported to Europe. In 2009 Finland was the biggest market for Russian pellets; 160,000 tonnes was imported. Denmark is the second largest market and the Danish import from Russia has increased from 87,000 tonnes in 2009 to 194,000 tonnes in 2011 (Danmarks Statistik 2012), which place Russia as the fourth largest contributor to the Danish pellet import.

The Russian pellet production capacity is expected to grow due to a growing demand, mainly from Europe and due to an abundant resource potential. The amount of forest residues currently produced is estimated capable of supporting an annual production of 20 million tonnes of pellets (Cocchi, Nikolaisen et al. 2011).

11.1.6.7. Wood resource potential

From North West Russia the total potential of wood for energy is estimated to 31 million solid m3 (223 PJ) (Gerasimov and Karjalainen 2009); 21.8 million m3 as logging residues and 9 million m3 from sawmills and plywood production. Currently (reference year 2006) about 40% of the allowable cut is exploited. If fully exploited, north western Russia could provide 73.5 million m3 of energy wood (529 PJ), and additionally 30.5 million m3 (220 PJ) from thinnings and wood industry residues.

11.1.6.8. Challenges to sustainability

According to official data, in 2011 illegal logging equalled 1.2-1.8 million cubic metres and over 21000 offences were uncovered (FAO 2012), accounting for app. 1 % of the total harvest in forests. Independent assessments come to other conclusions. The WWF Russia and the World Bank estimate that up to 20 % (35-40 million m3) of timber harvested in the Russian Federation is of illegal origin. Illegal logging is more widespread in the export-oriented forest regions, along the border with China and, the Irkutsk Region and the Primorye Territories. According to assessments by nongovernmental organizations, up to 50 % of the harvested timber in these regions may be illegal (FAO 2012).

11.2. General Europe

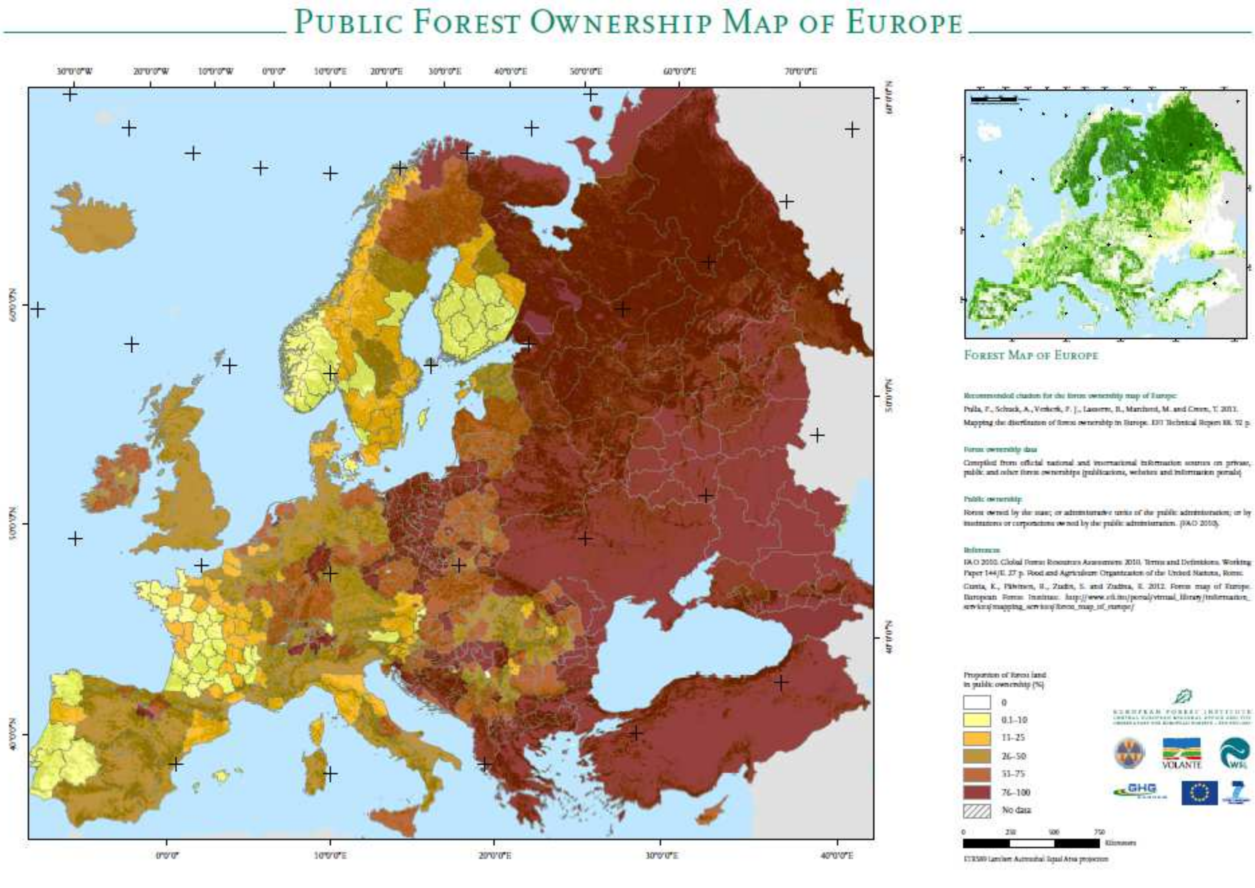


Figure 70. Public forest ownership in Europe (Pulla, Schuck et al. 2013).

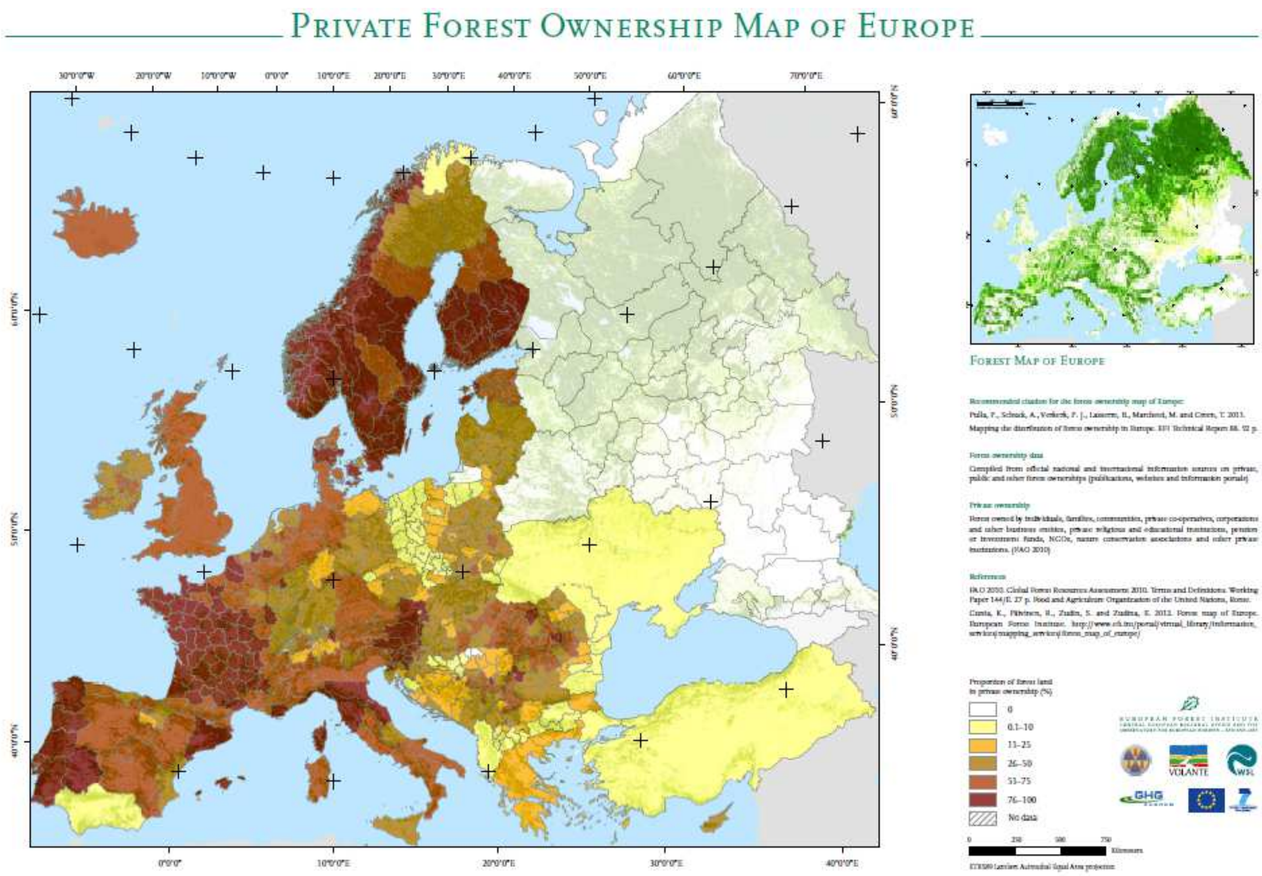


Figure 71. Private forest ownership in Europe (Pulla, Schuck et al. 2013).

Table 28. Actual and potential wood supplies in Europe (EU27) (MCPFE/EC/UNECE/FAO 2010).

Source of wood supply	Current use (2005)		Additional bio-technical potential*		Additional socio-economic potential**	
Stemwood (Forest area available for wood supply (FAWS))	355.2	68%	232	31%	81.2	35%
Above-ground biomass (FAWS)						
- from current harvest	11.2	2%	148.8	20%	52.1	22%
- from additional harvest		0%	28.8	4%	10.1	4%
Below-ground biomass (FAWS)	2.6	1%	176.2	23%	0	0%
Other wooded land	1.1	0%	18.7	2%	6.5	3%
Trees outside forest	7.1	1%	3.6	0%	1.3	1%
Forest Expansion	0	0%	65.1	9%	22.8	10%
Wood fibre from agriculture	0	0%	25	3%	18.7	8%
Co-products and residues from wood-processing industry	113.8	22%	2	0%	2	1%
Post-consumer recovered wood	28.6	6%	52.5	7%	39	17%
SUM	519.6	100%	752.7	100%	233.7	100%

Table 2: Importance of wood supply sources (million (M) m^3 round wood equivalent) according to UNECE/FAO study on Potential Sustainable Wood Supply in Europe
*Describes how much wood could be physically removed from the forest on a sustainable level in addition to the current harvest, based on the biological increment, and subtracting harvest losses, and accounting for bark, if the wood was harvested. Number is influenced by site conditions, forest management and harvesting efficiency.
**Describes how much wood could be cut and brought to formal and informal markets in addition to what is already used and marketed. Figure is mainly driven by harvesting cost, wood prices and related profit margins.

11.2.1. Challenges to sustainability in Europe

The challenges to sustainable mobilization of wood in Europe reviewed by international organizations in 2010 (MCPFE/EC/UNECE/FAO 2010)

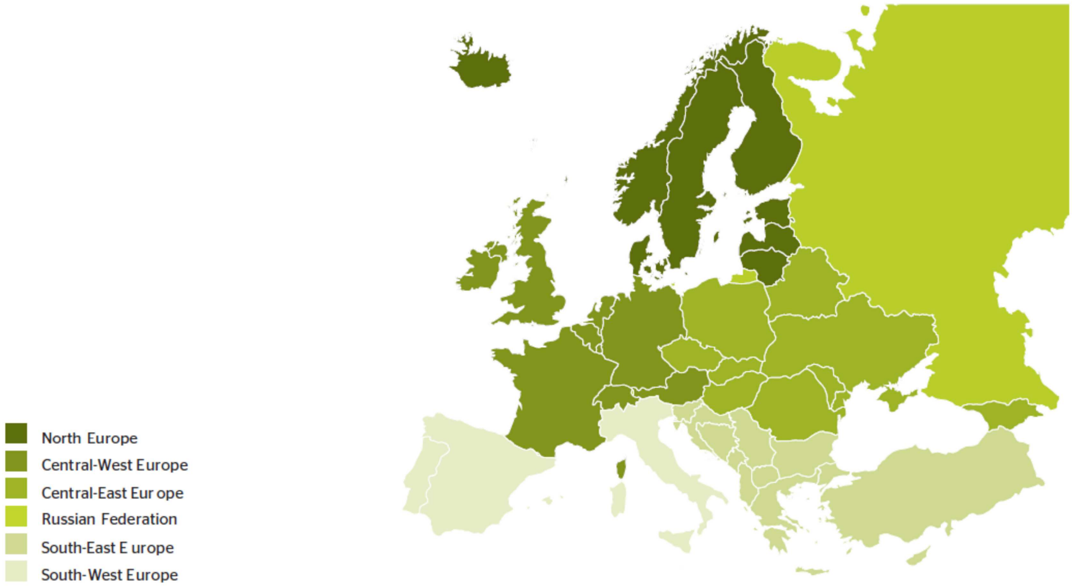


Figure 72. The European regions for which FOREST EUROPE have synthesized national information on progress of sustainable forest management.

11.2.1.1. Available data and frameworks

The most comprehensive review on sustainable forest management in Europe has been performed within the framework of the pan European process, FOREST EUROPE, formerly known as the Ministerial Conference on Protection of Forests in Europe. At the national level, the reporting to FOREST EUROPE is coordinated with the reporting to FAO's Global Forest Resource Assessment, and the European reviews of sustainable forest management are also made in cooperation with UNECE/FAO. The reviews are based on national reporting to FOREST EUROPE in 1990, 2000, 2005, and 2010 (the same years as for the UNECE/FAO of FAO forest resources assessments), data from International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests, Level II) and related projects. A review was made in 2007 (MCPFE 2007), and again in 2011 (FOREST EUROPE, UNECE et al. 2011).

The reviews comprehensively analyse the state and sustainability challenges of European forests, including the Russian Federation. The review is organised according to the six criteria of the pan European SFM framework, with a total of 36 indicators developed to measure these criteria. The indicators are quantitative or qualitative parameters that relate to one of the criteria and assess a condition or a direction over time (MCPFE 2007). The six criteria address the all aspects that are usually included in frameworks for sustainable forest management, including for example sustainable yield, contribution to global carbon cycles, biodiversity, soil, water, and socio-economic functions.

The framework furthermore includes a set of 17 qualitative indicators which have been developed to describe the state of national policies, institutions, and instruments for SFM. The FOREST EUROPE framework also includes other elements than the criteria and indicators (C&I). One of these is the Pan European Operational Level Guidelines that also serve as a basis for the SFM framework of the PEFC forest certification system. Other elements are the Guidelines for Afforestation and Reforestation, and a Common Approach to National Forest Programmes in Europe.

The Maintenance and appropriate enhancement of forest resources and their contribution to global carbon cycles;
Maintenance of forest ecosystems' health and vitality;
Maintenance and encouragement of productive functions of forests (wood and non-wood);
Maintenance, conservation and appropriate enhancement of biological diversity in forest ecosystems;
Maintenance, conservation and appropriate enhancement of protective functions in forest manage-ment (notably soil and water); and
Maintenance of other socio-economic functions and conditions.

Figure 73. The six criteria of FOREST EUROPE's SFM framework (http://www.foresteurope.org/sfm_criteria/guidelines).

One of four main challenges/opportunities identified for forest policy in Europe is the ambitious targets for renewable energy, which already have and probably will continue to result in an increased use of wood for energy. Other of the four challenges that may potentially get in conflict with the production of wood for energy is that forests should contribute to climate change mitigation by storing and sequestering carbon.

11.2.1.2. Carbon

The amount of carbon stored in the living biomass of European forests has been increasing two couple of decades, and also within each region, except the Russian Federation, which experienced a decrease in carbon stocks from 1990-2005, and only a small increase from 2005-2010 (Table 29).

During the period 2005 to 2010, 870 million tonnes of CO_2 were removed from the atmosphere and sequestered by the European forests (including the Russian Federation). This corresponds to about 10% of the GHG emissions in Europe (FOREST EUROPE, UNECE et al. 2011). The removals by EU27 alone were 430 million tonnes of CO_2. The stocks of dead organic matter and soil organic carbon also seem to have increased, but data are uncertain.

Table 29. Carbon stocks in forest biomass. From (FOREST EUROPE, UNECE et al. 2011).

Region	Carbon stock in biomass Mt C				Annual change %	
	1990	2000	2005	2010	1990-2005	2005-2010
Russian Federation	32 504	32 157	32 210	32 500	-0.06	0.18
North Europe	2 666	2 882	3 011	3 115	0.86	0.69
Central-West Europe	2 625	2 985	3 232	3 410	1.54	1.10
Central-East Europe	2 934	3 398	3 627	3 988	1.57	1.99
South-West Europe	773	972	1 014	1 082	2.07	1.35
South-East Europe	1 549	1 743	1 846	2 038	1.28	2.07
Europe	43 052	44 136	44 940	46 132	0.29	0.53
Europe without the Russian Federation	10 548	11 979	12 730	13 632	1.38	1.42
EU-27	7 806	8 782	9 317	9 901	1.29	1.25

Part of the accumulated carbon is due to afforestation. The European forest area (including Russia) increased with 19 million ha from 1990 to 2010 and of these 5.1 million ha were afforested from 2005 to 2010. The total forest area in 2010 was then 1.02 billion ha

Part of the increase in C stores may also be attributed to a skewed age distribution with a higher percentage of younger stand ages, where carbon sequestration is higher. This is e.g. the case in Norway. For European countries, without the Russian Federation, 12% of the forests are younger than 20 years, 43% are between 20 and 80 years, 18% are above 80 years, and 27 % are uneven-aged or non-categorized.

Table 30. Felling rates in European forests. From (FOREST EUROPE, UNECE et al. 2011).

Region	Felling rate (%)
Russian Federation	19.9
North Europe	70.9
Central-West Europe	65.0
Central-East Europe	57.2
South-West Europe	42.1
South-East Europe	46.9
Europe	38.9
Europe without the Russian Federation	62.4
EU-27	64.2

As the pressure on forests and other wooded land to deliver wood for energy and other products increases, it will increasingly be a challenge to keep up the current levels of stored forest carbon in the living biomass.

When harvest residues are removed for energy, there will also be a decreased input of organic matter and carbon to the soil.

So far, concerns over forest ecosystem carbon stocks have especially been identified for the Russian Federation. In the Russian Federation, there is furthermore concern over the decreasing area of other wooded land, which also leads to a decrease in the country's ecosystem carbon stock. In other parts of Europe, the carbon stocks are currently increasing.

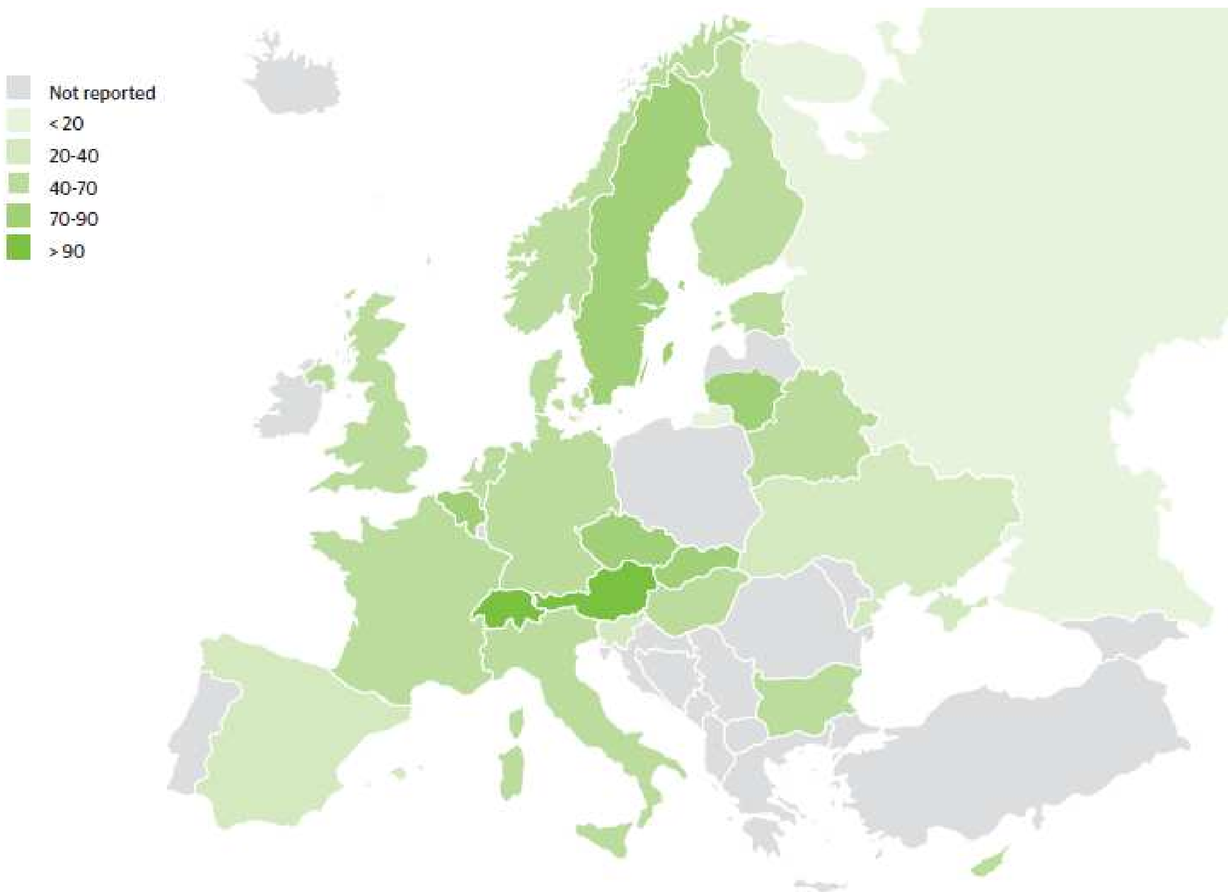


Figure 74. Geographical distribution of felling rates in Europe 2010. Adapted from (FOREST EUROPE, UNECE et al. 2011), figure 31.

In Europe overall, the growing stock has increased faster than area, which means that average standing volume of wood per hectare, and thus also the carbon stock, has increased during the last 20 years (FOREST EUROPE, UNECE et al. 2011). Currently, European forests thus sequester increasing amounts of carbon in tree biomass. This trend may change if the utilization of forests is intensified to produce more wood fuels for bioenergy production.

11.2.1.3. Biodiversity

A new EU biodiversity strategy, 'Our life insurance, our natural capital: an EU biodiversity strategy to 2020', (European Commission 2011) was adopted by the European Commission in May 2011 (Europan Environment Agency 2012). The strategy is built around six mutually supportive targets which address the main drivers of biodiversity loss and aim to reduce the key pressures on nature and ecosystem services in the EU. Each target is further translated into a set of time-bound actions and other accompanying measures. The strategy also highlights the need to enhance contributions from other environmental policies and initiatives including sectorial integration across EU policies such as agriculture, fisheries, forestry, water, climate and energy (European Commission 2011). The six key targets are the following:

• Target 1: Fully implement the Birds and Habitats Directives.

• Target 2: Maintain and restore ecosystems and their services.

• Target 3: Increase the contribution of agriculture and forestry to maintaining and enhancing biodiversity.

• Target 4: Ensure the sustainable use of fisheries resources.

• Target 5: Combat invasive alien species.

• Target 6: Help avert global biodiversity loss.

In order to improve and create dynamic forest policies, FOREST EUROPE has stepped up efforts to:

a. consolidate tools for sustainable forest management and improve monitoring and reporting,
b. strength efforts against illegal logging,
c. develop a common approach of valuation of forests ecosystem services with the aim of raising awareness of its contributions to society wellness,
d. emphasize the social aspects of forestry and the role of forests in the transition to a green economy.

FOREST EUROPE's SFM framework includes nine indicators for monitoring of biodiversity value in participating countries (Table 31).

Table 31.Biodiversity indicators of FOREST EUROPE (FOREST EUROPE, UNECE et al. 2011).

4.1. Tree species composition	Area of forest and other wooded land, classified by number of tree species occurring and by forest type
4.2 Regeneration	Area of regeneration within even-aged stands and uneven-aged stands, classified by regeneration type
4.3 Naturalness	Area of forest and other wooded land, classified by “undisturbed by man”, by “semi-natural” or by “plantations”, each by forest type
4.4 Introduced tree species	Area of forest and other wooded land dominated by introduced tree species
4.5 Deadwood	Volume of standing deadwood and of lying deadwood on forest and other wooded land classified by forest type
4.6 Genetic resources	Area managed for conservation and utilisation of forest tree genetic resources (in situ and ex situ gene conservation) and area managed for seed production
4.7 Landscape pattern	Landscape-level spatial pattern of forest cover
4.8 Threatened forest species	Number of threatened forest species, classified according to IUCN Red List categories in relation to total number of forest species
4.9 Protected forests	Area of forest and other wooded land protected to conserve biodiversity, landscapes and specific natural elements, according to MCPFE Assessment Guidelines

Protected forests are important to maintain and enhance biodiversity. The area of protected forests is expanding in Europe generally, and has increased by around half a million hectares annually over the last 10 years due to policies to improve biodiversity. In Europe without the Russian Federation, about 10% of forests are protected (FOREST EUROPE, UNECE et al. 2011).

The level of forest protection in Finland and Ireland corresponds to the average European level, while it is lower in other north European countries. However, in most north European countries a high proportion of forest is covered by management plans. A forest management plan is the basis for sustainable management of forests, but do not per se lead to sustainable management of the forest.

However, monitoring shows that forest management practices in Europe generally have changed towards greater integration of biodiversity aspects; deadwood and vulnerable small biotopes are maintained in forests managed for wood production, and the use of natural regeneration and mixed tree species stands increases. The long-term monitoring of biodiversity indicates that the decline of threatened species has slowed down even if the number of threatened species is still declining (FOREST EUROPE, UNECE et al. 2011).

One of the main challenges to biodiversity in northern Europe is as such to continue the positive developments and changes in practices towards regeneration and mixed species stands. Studies show that education of forest entrepreneurs is crucial to avoid for example that dead wood at progressed decay stages are removed when forest residues are harvested (Jonsell 2008). The review by Jonsell also shows that it may be important for example to leave wood of deciduous species in areas dominated by coniferous species as most of the rare species may be associated with broad leaves in such areas.

11.2.1.4. Soil

FOREST EUROPE uses three indicators to infer about the soil condition.

- C/N index ratio
- pH and base saturation (BS)
- Soil organic carbon contents

The C/N index ratio between the C/N ratio of the forest floor and the top mineral soil expresses the disturbance of the organic matter and nitrogen cycling with the forest health and vitality being at risk. The reasoning is that in healthy forests the C/N ratio of the forest floor is distinctly higher than in the mineral soil. A C/N index ratio less than 1 will thus indicate a disturbed condition, with the atmospheric nitrogen deposition usually being responsible for such conditions. On location with a high nitrogen deposition (>20 kg ha^{-1} yr^{-1}), there is also an increased risk of nitrate leaching to ground- and surface water, leading to eutrophication and with consequences for groundwater quality.

Base saturation measures the soil's buffering capacity against soil acidification. Growth causes a natural acidification, but atmospheric deposition of both sulphur and nitrogen are often the main reasons for soil acidification, even if also biomass harvesting may contribute indirectly; the organic matter releases alkalinity when decomposed, which is forgone when the biomass is being removed. Nitrogen deposition may also stimulate growth, but if added in excess without other nutrients, imbalances in the nutrition may occur. The deposition of sulphur is at a fairly even level in Europe, except for lower levels in the Alps, northern Scandinavia and in parts of France and the Iberian Peninsula. The highest atmospheric deposition of nitrogen is in central Europe, from northern Italy to southern Scandinavia. Critical loads for acidity and nitrogen.

Finally, the soil contains storages of carbon which it is important to maintain, or even increase for climate change mitigation and soil structure, which is also a determinant of soil fertility.

These soil indicators were measured under ICP Forests at two occasions (i.e. not for all signatory countries to FOREST EUROPE), first during the period 1986-1996, and later during the period 2004-2007. It was observed that N deposition continues to cause disturbances in soil conditions, as the C/N index ratio was lower than 1 on 14% of 2,738 observation plots in Europe, especially plots located in Central-Western Europe, parts of Central-Eastern Europe and the Baltic States.

The pH was found to increase in the acid forest soils with pH < 4.0, but decreased in forest soils with pH > 4.0, and similarly, base saturation increased in the acidified forest soils with an initial BS < 20% and decreased in forest soils with initial BS > 20%. FOREST EUROPE considers the tendency to both acidification and eutrophication of forest soils to be potentially of concern.

The base saturation decreased significantly in the topsoil of certain soil types, Regosols, Arenosols (younger less developed soil) and Stagnosols (soil with stagnating water), while it increased significantly in Luvisols (high base status) and Gleysols (groundwater affected soils). Arenosols are mainly found Central-East of Europe, in the countries along the southern coasts of the Baltic Sea, and Regosols on the Iberian Peninsula. Luvisols are found scattered all over Europe, except for northern Scandinavia, while Gleysols are most common in the UK, Ireland, North-East Europe and along a southwest-northeast belt in the Russian part of Europe.

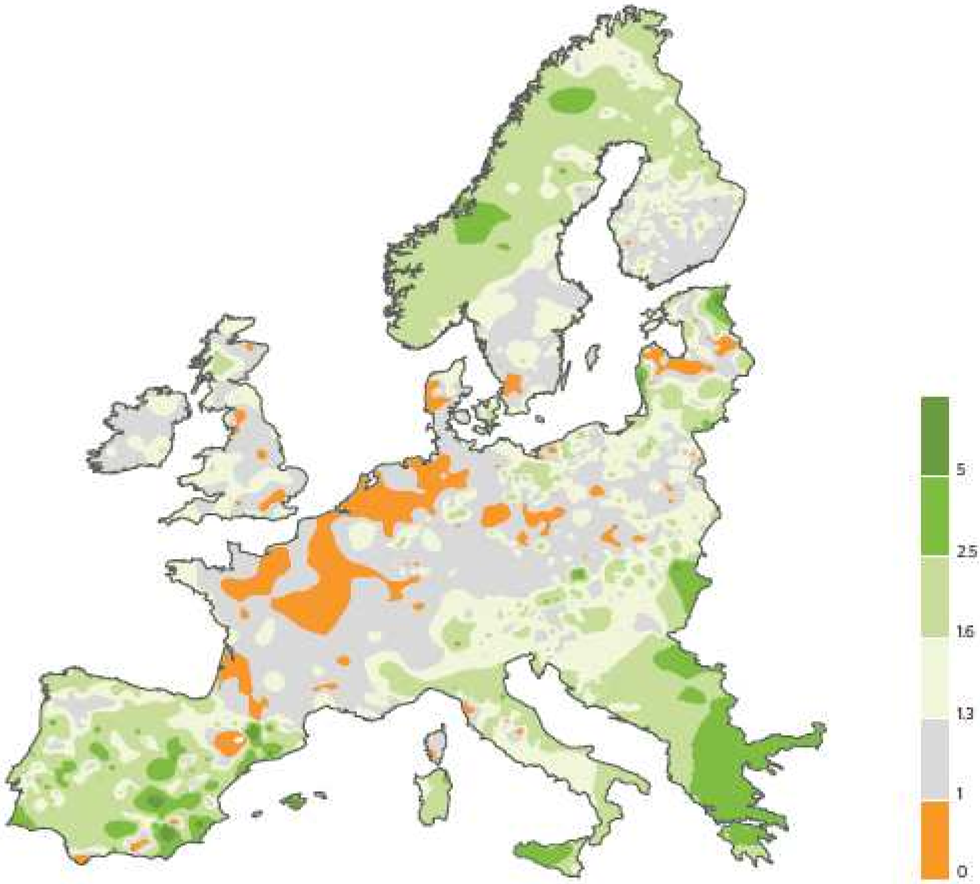
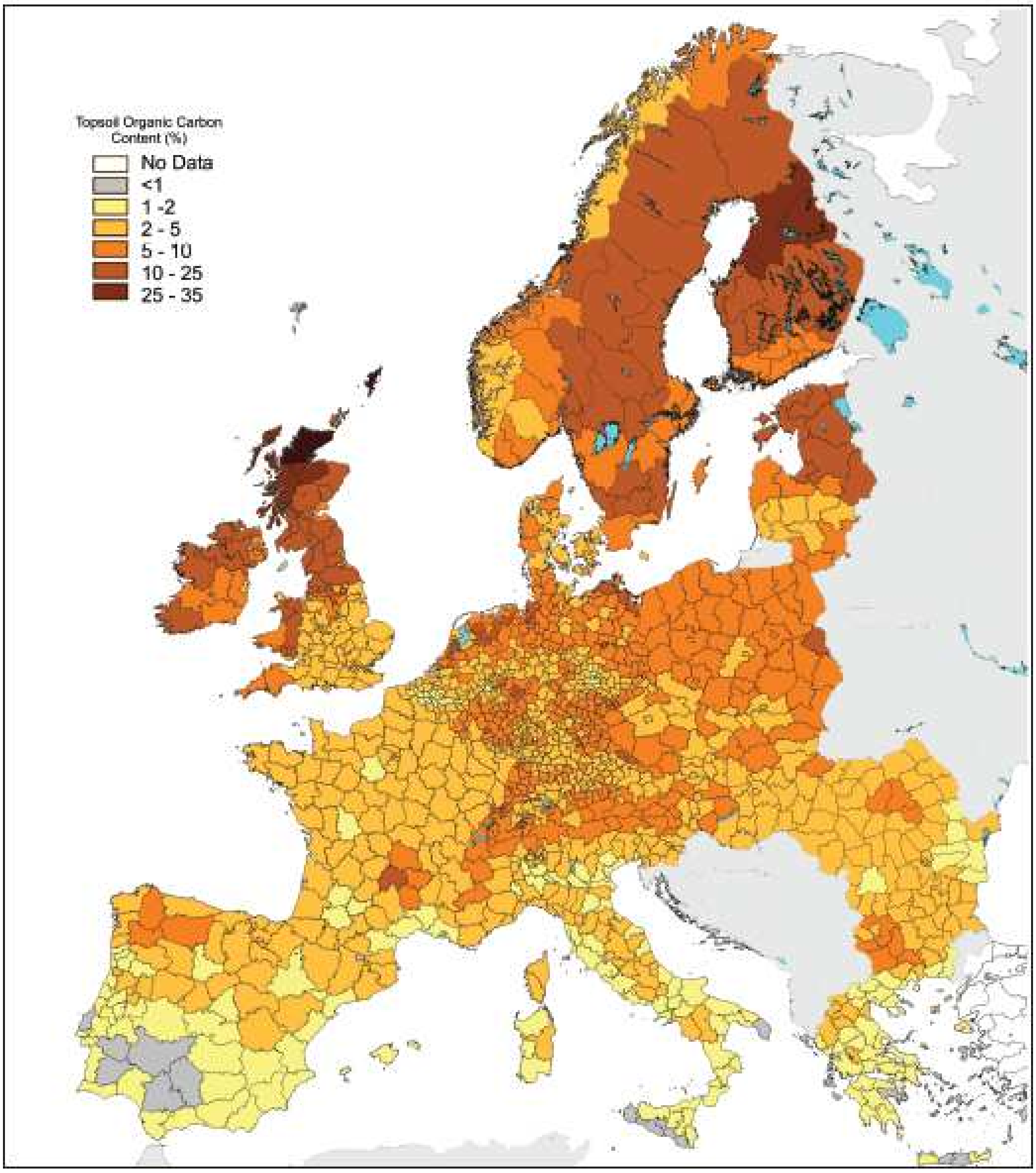


Figure 75. C/N ratio of forest soils in Europe. From (FOREST EUROPE, UNECE et al. 2011).

The amount of soil organic carbon varies widely across Europe, with the most carbon rich soils being located in northern UK, Scandinavia and the Baltic states (Figure 76). Generally, there are higher carbon contents in north European soils compared to southern Europe. For the majority of the revisited sites, an increase in the concentration of organic carbon was found in the upper soil layer, while both increases and decreases were found for the soil carbon contents. However, methodological differences between the surveys make it difficult to draw well-documented conclusions.



The map above shows the distribution of soil organic carbon, a major component of organic matter, according to administrative units; it emphasises the generally low levels in southern Europe compared to the north (RH).

Figure 76. Organic content in soils in Europe. From http://eusoils.jrc.ec.europa.eu/projects/soil_atlas/.

Intensified harvesting of forest biomass may alleviate problems with excess nitrogen as more nitrogen is removed from the site (Skogsstyrelsen 2007), but it also has the potential to contribute to acidification and decreased carbon stores in the soil.

11.2.1.5. Pesticides and fertilizer

In terms of pesticide use the Nordic countries are characterized by low consumption compared to Europe as a whole (Willoughby, Balandier et al. 2009, McCarthy, Bentsen et al. 2011). The annual use of pesticides is reported to 0.05-16.3 g active ingredient (a.i.) per ha. The low consumption is a consequence of forest policies promoting non-chemical forest management, but also climatic conditions in the Nordic countries favour non-chemical management (McCarthy, Bentsen et al. 2011). In Irish and UK forest management pesticide use is more frequent. In terms of herbicides the consumption in Ireland is 5.9 g a.i. per ha, and 11.3 g a.i. per ha in the UK. The total pesticide use is not reported for Ireland, but in the UK the widespread use of urea for stump treatment against the fungus *Heterobasidion annosum* brings the total consumption to 182 g a.i. per ha. Statistics on pesticide use in Western European forestry are not available. In France herbicides are commonly used for vegetation management, whereas in Germany herbicides are only used on an occasional basis. Pesticide use in Southern European forestry is not very well documented. They are, however used as either the main alternative or occasionally. Figures indicate a total use of pesticides in the range of 1.6 to 13.8 g a.i. per ha (McCarthy, Bentsen et al. 2011). Pesticides are used in the Eastern European countries as the main alternative to other means of vegetation management and plant protection. Data for the Czech Republic show a comparably high consumption of pesticides in total of 696 g a.i. per ha of which 45.9 g are applied as herbicides. The remainder is to a large extent applied as insecticides (McCarthy, Bentsen et al. 2011). The corresponding data for Slovakia are 2.8 g a.i. per ha as herbicides and 4.2 g a.i. per ha in total pesticide use, and for Bulgaria 0.15 and 1.2 g a.i. per ha respectively.

11.2.1.6. Forest disturbances

Several disturbances cause damage to forests in Europe, including biotic or abiotic disturbances, and natural and human induced disturbances (FOREST EUROPE, UNECE et al. 2011). Biotic agents include insects and diseases, and grazing wildlife and cattle, while abiotic agents include fire, storm, wind, snow, drought, mudflow and avalanches.

Insects and diseases as well as wildlife are the most frequently reported damaging agents in European forests, but the level of damage is often unknown. The area affected by insect and storm damages has been increasing over all three reporting years 1990, 2005 and 2010 for Europe excluding Russia. Damages due to snow and fire also cause significant primary losses regionally and locally.

Speaking of catastrophic events and by volume, storms are responsible for more than 50% of all primary abiotic and biotic damage. More than 130 separate wind storms have been identified as causing significant damage to European forests since the 1950s (approximately 2 per year) The primary damage cause by the storm may lead to subsequent secondary damages, such as attacks from bark beetles, or damages from fire, sun, snow/ice and additional wind damage. Tertiary damages may also occur in form or production losses due to shortened forest rotations and other long-term constraints on forest operations. Damage by wind to European forests is clearly increasing, and is expected to continue to increase, partly due to the increased growing stock.

The extent of the damages and the type of damages vary between European regions, but generally less than 1% seems to be damaged. Exceptions are insect damages in Europe (without the Russian Federation), and damages due to wildlife and grazing in 2005. However, damages might be under-reported.

Table 32. Forest Damage trends 1990-2005 (1000 ha). From (FOREST EUROPE, UNECE et al. 2011).

		Insects & disease			Wildlife & grazing			Storm, wind & snow			Fires		
	Country	1990	2000	2005	1990	2000	2005	1990	2000	2005	1990	2000	2005
Europe	Forest area with damage (million ha)	5.2	10.3	7.9	1.0	1.0	2.4	1.2	2.4	4.0	1.0	1.5	1.4
	Represented forest area (million ha)	928.1	968.4	968.9	93.7	107.8	127.0	944.8	978.9	985.8	987.4	1 019.4	979.1
	Represented forest area (%)	91.0	94.9	95.0	9.2	10.6	12.5	92.6	96.0	96.7	96.8	99.9	96.0
	Forest area with damage (%)	0.6	1.1	0.8	1.1	0.9	1.9	0.1	0.2	0.4	0.1	0.2	0.1
Europe without the Russian Federation	Forest area with damage (million ha)	3.4	4.4	5.1	1.0	1.0	2.4	1.0	1.9	2.6	0.3	0.3	0.3
	Represented forest area (million ha)	119.0	159.3	159.9	93.7	107.8	127.0	135.7	169.9	176.7	178.3	210.3	170.0
	Represented forest area (%)	56.4	75.6	75.8	44.5	51.1	60.2	64.3	80.6	83.8	84.6	99.8	80.6
	Forest area with damage (%)	2.8	2.8	3.2	1.1	0.9	1.9	0.8	1.1	1.5	0.2	0.1	0.2

A reduction of the growing stock, e.g. by harvesting wood for energy, could perhaps be measure to decrease the risk of catastrophic events if managed properly.

11.2.1.7. Policy and governance

On the basis of the information provided for the State of Europe's Forests 2010 (FOREST EUROPE, UNECE et al. 2011), four major challenges and opportunities for forest policy in Europe have been identified. The forest sector is playing a major role in climate change mitigation through carbon sequestration and substitution of non-renewable energy and materials. At the same time it must adapt to a changing climate, which requires significant investment. The challenge is thus to find and deliver the optimum balance among the various forest functions in the context of changing climate and societal needs. Ambitious targets for renewable energy throughout Europe have resulted in more use of wood for energy, and there are clear signals that this trend will continue. The challenge is not only to mobilize more wood to meet the targets but also to reconcile this mobilization with the other dimensions of sustainable forest management. It appears that there has been strong progress in the conservation of forest biodiversity, although there are still significant monitoring and measurement problems. The challenge is to reconcile measures for biodiversity conservation with the more intensive forest management likely to be necessary to meet the expected higher demands for wood, including for renewable energy. The European forest sector already displays many of the characteristics of a green economy and has the potential to play a major, even exemplary, role in the emerging green economy – notably by promoting sustainable production and consumption patterns, green building, green jobs in the sector, and the supply of renewable energy, as well as developing payment for ecosystem services. The challenge is to achieve this potential by strongly developing the "green" features of the forest sector.

The forest sector, including wood processing and pulp and paper industries, contributes on average 1 % of GDP (gross domestic product). However, during the last few years, most regions have shown an increase in net value added and net entrepreneurial income of forestry enterprises. The importance and recognition of other forest services, as source of energy, recreation and cultural and spiritual values, are increasing. Rising energy prices and political initiatives to promote the use of wood for energy have increased the value of small timber assortments.

The need for cross-sectorial approaches and innovation in the forest sector and policy development and implementation is widely acknowledged

Most countries have, or are developing, general objectives and adequate policy instruments for the forest sector. However, there is still a need for improved coordination and coherence among multiple policies which affect the forest and wood sector as well as for the formulation of more target oriented objectives.

11.2.2. Summary of sustainability challenges in Europe

FOREST EUROPE summarises that "in most of North Europe, the boreal forest is at the centre of the landscape. There is an intensive use of the resource and a sophisticated and well-resourced institutional structure. Forest-related questions have a high policy importance in the region. Areas of concern identified are the large area at risk from eutrophication; the Carbon/Nitrogen ratio in forest soil approaching warning level in two countries; and the low percentage of forest protected for biodiversity in some countries".

FOREST EUROPE summarises: "Central-West Europe contains many densely populated and highly prosperous urban countries, although there are significant rural and mountainous areas, which is where most of the forests are. Forest institutions are stable and well-resourced, even if they lack political weight relative to other parts of society, which can mobilize more financial and human resources. Areas of concern identified are the high percentage of land area at risk of eutrophication from nitrogen deposition; the Carbon/Nitrogen ratio near warning level for soil imbalances in some countries; problems with landscape pattern and fragmentation, negative net entrepreneurial revenues in a few countries; negligible share of wood in total energy supply in a few countries; and the small share of the total workforce engaged in the forest sector.

FORESTS EUROPE: The countries in Central-East Europe were all centrally planned 25 years ago, but many have now been transformed and are increasingly prosperous. Five countries in this group are now members of the European Union. Ecologically the country group is heterogeneous, running from the Alps to the Caucasus and the Volga basin. Areas of concern identified are the decline in forest cover in one country; the fact that the entire land area of the region is at risk of eutrophication from nitrogen deposition; the Carbon/Nitrogen ratio near warning level for soil imbalance in one country; high defoliation level in one country; generally low per hectare values for marketed non-wood goods and services; the small share of the total workforce engaged in the forest sector; low levels of wood consumption; and the low reported share of wood in total energy supply.

FORESTS EUROPE: In South-West Europe, most countries have a distinctively Mediterranean forest on much, but not all, of their territory. Despite the threats, some areas are managed intensively, sometimes with introduced species. There are serious information gaps. Areas of concern identified are the high percentage of land at risk of eutrophication due to nitrogen input; significant fire damage; high fragmentation; and negative trends for forest landscape pattern in some countries.

Most of the countries in South-East Europe have rather large rural populations and low per capita income by European standards. Some have new institutions which emerged after the conflicts in the former

Yugoslavia. Fire is an issue throughout the region. In one country, the forest itself is under severe pressure from overgrazing and over- cutting (mostly for fuel) by the rural population. It appears that, in many areas, the forests are not intensively managed and not well protected for biodiversity – but information is very weak, so this cannot be verified. Due to the lack of adequate information provided, and possibly also because the relevant forest-sector information does not exist at the national level, it is not possible to say with any objectivity whether or not forest management is sustainable. Areas of concern identified are one country with steeply falling forest cover and growing stock; nearly all land area of the region at risk of eutrophication due to nitrogen deposition; significant fire damage; fellings greater than net annual increment in one country; rather low per hectare values for marketed non-wood goods; several countries with a high share of single species stands; low share of forest protected for conservation of biodiversity in many countries; and low levels of wood consumption.

11.3. U.S.A.

11.3.1. Forest types

The forests in the U.S. can largely be divided into three biomes: the temperate coniferous forests zone in western and south-eastern U.S., savannah and scrublands in the central part, and temperate broadleaf and mixed forests in eastern USA. Forest covers 304 million ha corresponding to 33 % of the total land area. The forest area in the U.S. has increased from 296 million ha in 1990 to 304 million ha in 2010, an increase of 2.6 %. About 170 million ha are located in the 21 state north-eastern part of the U.S. and about 84 mill ha in the 13 state south-eastern part.

The temperate and boreal forest resource assessment (TBFRA) covering North America was last completed in year 2000 (UNECE and FAO 2000). Data on forest increment and carbon reservoirs are based on national reporting according to the Montreal process (United States Department of Agriculture 2011).

For more than 50 years removals of forest biomass from forests available for wood production has not exceeded biomass increment in the forests. In 2003 removals totalled 15.8 billion cubic feet (447 million m^3). In 2006 it had decreased to 15.5 billion (439 million m^3). The current (2006) exploitation rate is reported to 65 % in coniferous forests and 49 % in broadleaved forests (United States Department of Agriculture 2011).

According to the TBFRA 2000 the annual accumulation of Carbon in biomass was 166 Tg carbon yr^{-1} (equals 166 million tons) (UNECE and FAO 2000). This is reflected also in the recent report (Figure 77) showing a constant or increasing amount of carbon stored from 1990 to 2007 (United States Department of Agriculture 2011).

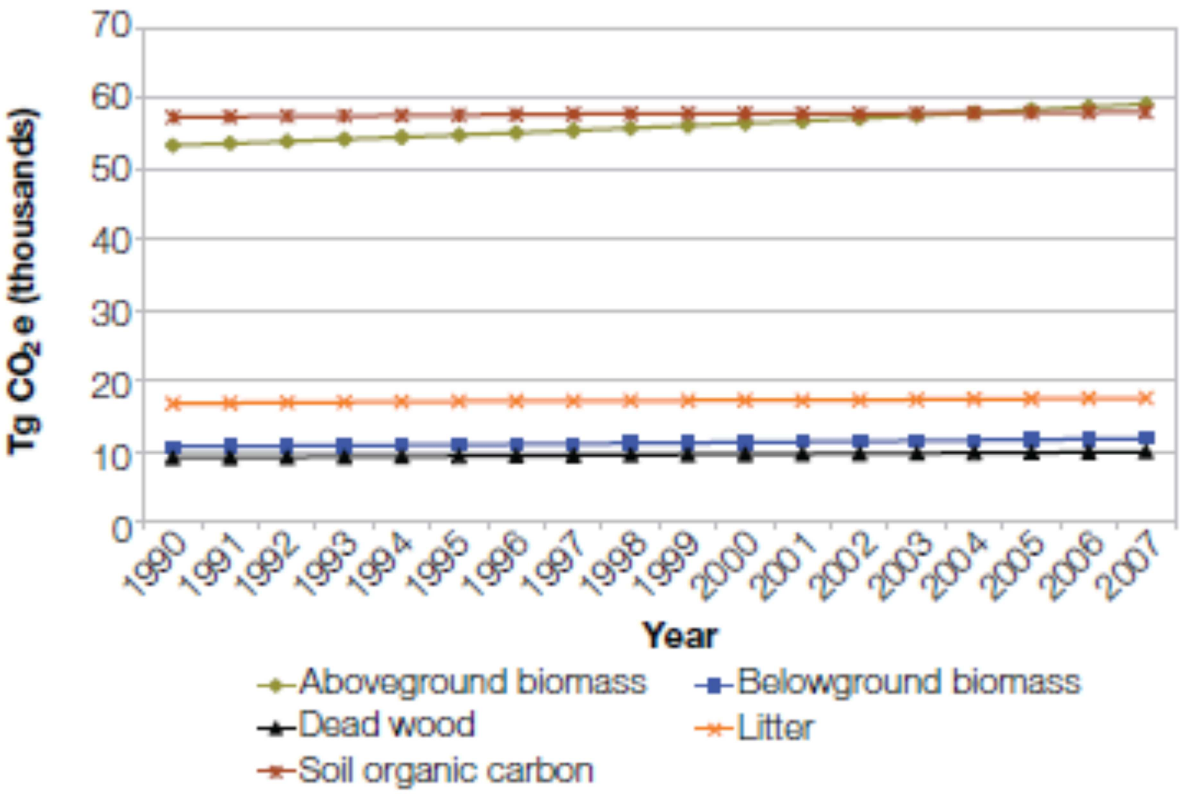


Figure 77. Carbon reservoirs in the forest in USA (United States Department of Agriculture 2011). One unit of CO_2e corresponds to 0.273 units of carbon.

11.3.2. Forest ownership

The forest ownership structure in the U.S. is characterised by 43% in public ownership and 57 % privately owned land (FAO 2010). The east is dominated by private ownership, while the west is dominated by public ownership (Figure 78). About 206 mill ha or 68% of the forests have a management plan. In the South, however, only 3% of family forest owners have written forest management plans and only 13% have received forest management advice (Kittler, Price et al. 2012).

The south-eastern U.S. is dominated by small-scale forestry, with the vast majority of the private forestland (54 mill ha out of about 81 mill ha) being owned by 5 million families and individuals (Kittler, Price et al. 2012). Kittler, Price et al. (2012) furthermore write that large industrial landowners from the pulp and paper industry in the South sold off most of their lands in the last two decades, and that wood from these lands may become available for pellet production.

The owner structure in south-eastern U.S., with several small owners is a challenge to verification of the biomass sustainability. For example, certification is less accessible for small scale owners compared to large industrial owners. Land in south-eastern U.S. owned by the pulp and paper industry were often certified by SFI, but it is yet to be seen if an export market for pellets can help maintain these lands under sustainable management in the future (Kittler, Price et al. 2012).

In the north-eastern USA, 76% of the forest is privately owned, and 24% is public forest. Of the privately owned forest, 73% is owned by family forest owners, and 27% is owned by business forest owners (USDA 2005). A development is on-going, where the forests are being parcelized and fragmentized for urban development (USDA 2005, Butler and Ma 2011). In this process, forest land is divided up and sold to multiple owners. Since 1993, 3.7 million family land-owners owned 37.8 million ha of forest, while in 2006, 4.8 million family landowners held 38.0 million ha of forest. The average size of family forest holdings decreased from about 10 ha in 1993 to about 8 ha in 2006. The turnover among these forest owners is also high, with about 17% of the land was owned by "new" owners in 2006, and amenity values being among the most important reasons for buying such forests.

Another trend in the northeast is, that forest products companies that have owned and managed forest land have sold off large amounts of land to institutional investors such as banks, pension funds, and insurance companies and to groups known as timber investment management organizations (USDA 2005).

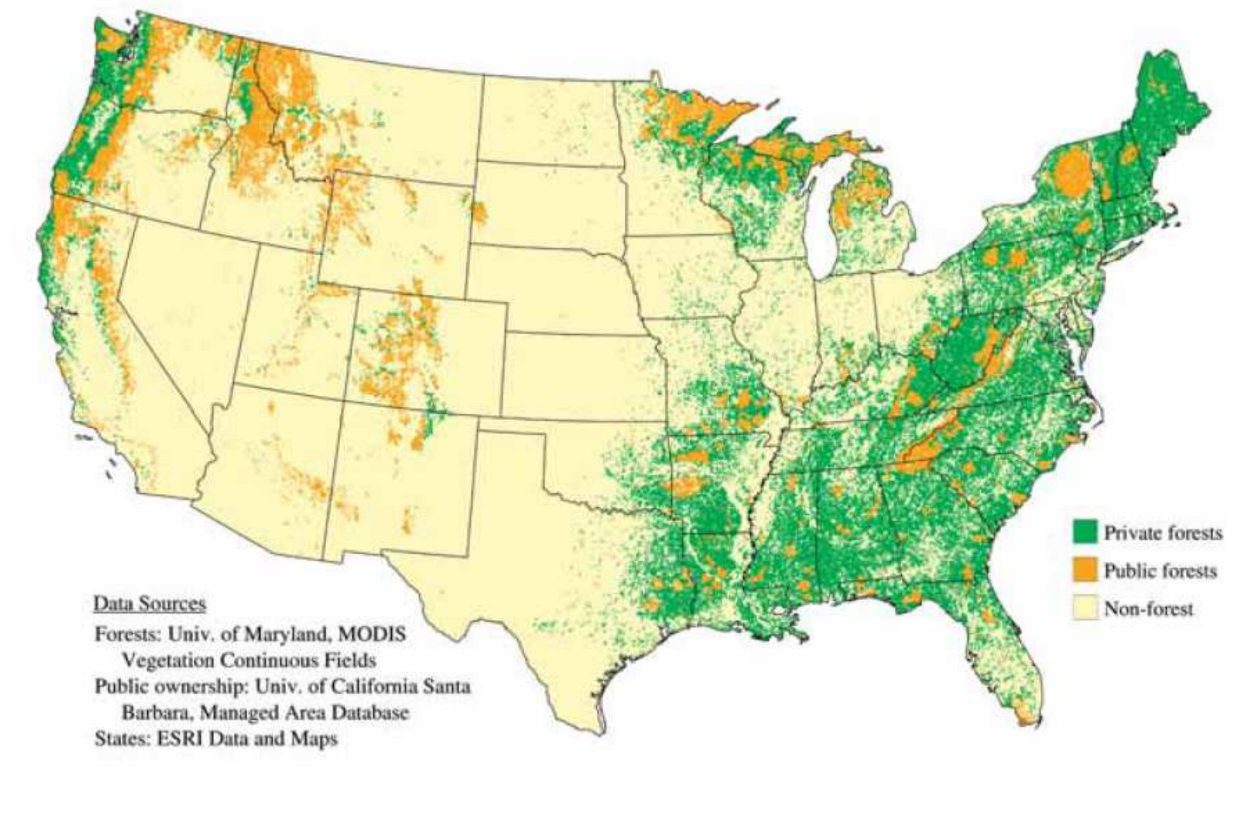


Figure 1. **Public and private forest ownership in the United States, 2003.**

Figure 78. Public and private ownership in the United States. From (Butler and Leatherberry 2004)

11.3.3. Legal and political framework

11.3.3.1. Forest management and legal status

The part of the forest area classified as primary forest constitutes 75 mill ha (25%), while 203 million ha (67 %) are classified as naturally regenerated forest, and 25 mill ha (8 %) as planted forest. The permanent forest estate covers 133 mill ha or 44%, while 30 mill ha or 10% are located in protected areas (FAO 2010).

Table 33. Levels of protection of forests of the U.S.A. (FAO 2010).

	Permanent forest estate		Forest in protected area		Forest with management plan	
	1000 ha	%	1000 ha	%	1000 ha	%
USA	133,014	44	30,225	10	206,084	68

11.3.3.2. Forest management and regulatory approaches

Forestry operations in the U.S. are regulated by a relatively complex set of laws, regulations, and non-regulatory policies at federal, state and local levels. At the federal level there are laws addressing for example multiple use, sustained yield, clean water, wilderness, endangered species, and protection of costal zones (USForestService 2011). States have adopted a wide variety of regulatory and non-regulatory programs that address forest-related environmental and land use issues (NAFO 2009). NAFO furthermore writes: "*Generally these are incorporated into federally approved programs under the federal statutes listed above, but many deal with other forestry issues as well. All 50 states have a State Forester, who is responsible for administering forestry programs and coordinating regulatory and non-regulatory programs administered by his department and other agencies. Some states have forest practices acts regulating all or most forest management activities. Some require reforestation after timber harvests. Some require local government approval to convert forestlands to non-forest uses. Some provide various kinds of tax incentives to encourage forest owners to keep their lands in forests. All states provide landowner education and technical assistance delivered by State Foresters, land grant colleges and universities, and other institutions, often with federal funding through the by U.S. Forest Service state and private forestry programs and Natural Resources Conservation Service extension service programs.".*

(Kittler, Price et al. 2012) furthermore writes for the south eastern region specifically: *Most states in the region rely on a small framework of water and forestry laws focused mainly on a variety of issues (e.g. water quality, fire management, pest management, and restocking) that are bound together by voluntary programs focused on outreach to landowners and loggers. State-level laws are often supplemented by local ordinances that offer a further degree of control over forestry activities at the local level. In a nationwide review of state-level regulations affecting forestry operations, (Ellefson, Kilgore et al. 2004)) found that among geographic regions in the U.S., the South has the highest portion of states that have no regulations of practices, or that only regulate under certain conditions. As a consequence, some states rely almost exclusively on voluntary approaches, with the forest industry historically playing a larger role than government in carrying out outreach to land. Stock Forest management or biomass harvesting guidelines may also exist at the owners or providing financial and/or technical assistance in the development of forest management plans (Ellefson, Kilgore et al. 2004). Voluntary programs most often take the form of cost share payments, technical assistance, grants and loans, education programs, preferential access to* *contracts with forest product companies, practice guidelines, and certification programs (Ellefson, Kilgore et al. 2004). Ellefson et al. found that forestry agencies in the South ranked order of program effectiveness to be: technical assistance, extension education, financial incentives, tax incentives, and regulatory programs.*

In the USA, three different forest certification systems are available: SFI, ATFS (both PEFC endorsed) and FSC. About 40 million ha or about 11% has been certified in total, with most of forest certified being located in the north- and southeast (Table 34).

Table 34. U.S. Forestland certified to SFI, FSC, and/or ATFS Standards by region (Lowe, Brogan et al. 2011). In the footnotes, states that have state forest biomass harvesting guidelines are shown in bold italics (Titus, Thiffault et al. 2012).

		Certified forest area			Dual certification			% of all forest land		
	Totalforest Land	SFI	FSC	ATFS	FSC/SFI	FSC/ATFS	Net Certified	All certified	FSC	SFI&ATFS
		(mill ha)						%		
Southeast[1]	87	8	1	6	-	-	15	18	1	17
Northeast[2]	70	10	12	3	7	1	17	24	17	19
West[3]	147	6	1	1	0	-	8	5	1	5
Total	304	24	14	11	7	1	40	13	4	11

[1]Southeast: Louisiana, Alabama, Arkansas, Mississippi, Georgia, South Carolina, Texas, Florida, Virginia, Oklahoma, North Carolina, Tennessee, ***Kentucky,*** [2]Northeast: ***Minnesota***, ***Maine***, ***Wisconsin***, ***Michigan***, ***New Hampshire***, Pennsylvania, Indiana, West Virginia, New York, ***Maryland***, Delaware, Ohio, ***Vermont***, ***Massachusetts***, Connecticut, Iowa, New Jersey, ***Missouri***, Illinois, [3]West: Washington, California, Oregon, Idaho, Montana, Hawaii, South Dakota, New Mexico, Colorado, Utah, Kansas, ***Nebraska***, Alaska, Arizona, Nevada, North Dakota, Wyoming.

In addition to the regulatory and non-regulatory approaches, cooperative projects between private landowners, states, and private foundations have sometimes been established to ensure the protection of critically important natural ecosystems (NAFO 2009).

11.3.3.3. Implications for biomass trade

All levels of regulatory and voluntary governance add up to a complex of requirements, with the biomass entering the market along different 'sustainability pathways', with none, one or more layers of requirements that may or may not have been controlled by the officials or private third parties (Figure 79). For U.S. pellets exported to the EU, another set of requirements may be added, if the EU decides on mandatory sustainability requirements for solid biomass, as already decided in the U.K.

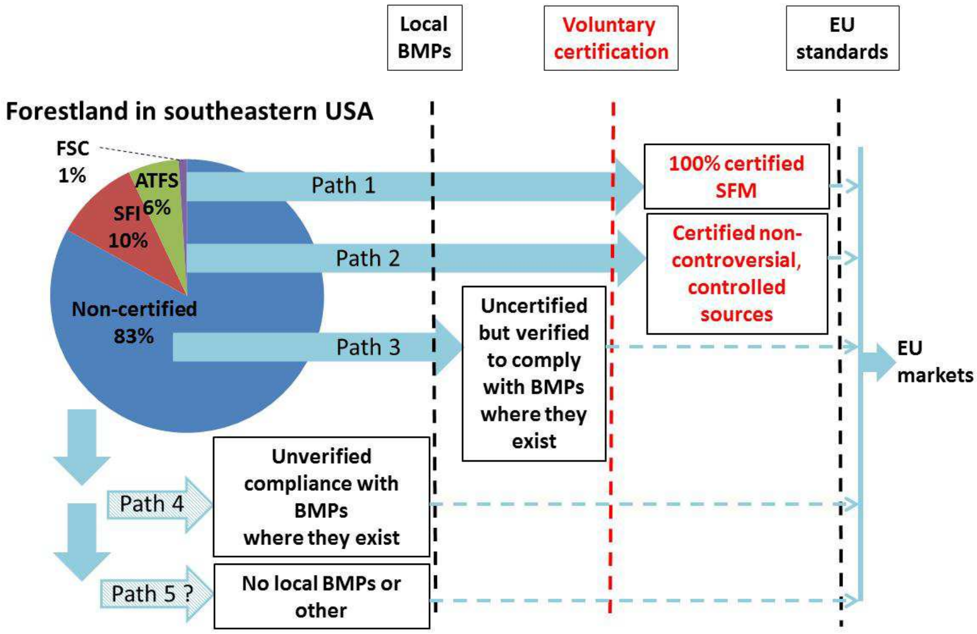


Figure 79. Multiple sustainability claims for southeaster exports to EU markets. Adapted from (Kittler, Price et al. 2012) by (Smith and Stupak 2012)

Kittler, Price et al. (2012) benchmarked four existing 'sustainability pathways' in south-eastern U.S. with EU sustainability requirements of EU RED, and found that forest certification covers all requirements except those related to greenhouse gas balances and air quality, and SFI and ATFS also does not adequately address exclusion of material from converted high carbon stock lands.

Table 35. Benchmarking of sustainability governance pathways in south-eastern U.S. with current EU sustainability requirements for liquid biomass fuels, EU RED. From (Kittler, Price et al. 2012).

EU renewable energy directive sustainability criteria

	PROCUREMENT PATHWAYS			
	Certified forest management	Controlled and mixed sourcing	Inspected compliance for stewardship plans and practices	Uninspected forest operations
Social impacts	fully	fully	fully	partially
Exclude biodiverse forests with decreased human intervention	fully	fully	fully	partially
Water impacts	fully	fully	fully	partially
Soil impacts	fully	partially	partially	does not address
Exclude high biodiversity lands	fully	partially	partially	does not address
Exclude wetlands and continuously forested areas	fully	partially	partially	does not address
Integrated pest management; reduced chemical use	fully	does not address	does not address	does not address
Exclude peat lands; new drainage prohibited	fully	does not address	does not address	does not address
Exclude high carbon stock lands	partially	does not address	does not address	does not address
Emission reduction >50%	does not address	does not address	does not address	does not address
GHG methodology defined	does not address	does not address	does not address	does not address
Air impacts	does not address	does not address	does not address	does not address

Procurement pathway *fully* addresses sustainability requirement
Procurement pathway *partially* addresses sustainability requirement
Procurement pathway does not address sustainability requirement

International conventions and agreements also help to ensure environmental values of forests, and the U.S. has ratified several conventions, declarations and agreements, including United Nations Framework Convention on Climate Change (UNFCCC), United Nations Convention to Combat Desertification (UNCCD), International Tropical Timber Agreement (ITTA), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), The Convention on Wetlands (Ramsar), World Heritage Contents (WHC), Non-Legally Binding Instrument for All Types of Forests (NLBI). Even if the Convention on Biological Diversity (CBD) is largely modelled after conservation laws in the USA, and despite that U.S. governmental analysis of the Convention's conservation provisions has concluded that existing U.S. laws already meet the commitments of the Convention, the USA is still one of the very few countries that have not ratified the convention (Snape III 2010). The others are Andorra, Iraq, Somalia. Instead the U.S. participates as an observing party.

11.3.4. Wood and wood fuel products

From 1990 to 2005, industrial wood production declined by 4 %, while wood fuel production was approximate halved during the same period. However, this trend has been reversed since 2005, with the wood pellet industry developing rapidly (Kittler, Price et al. 2012). Even if 13 companies (mostly focused on biopower) exited the U.S. wood bioenergy sector in 2011, there was at the same time a net increase of 39 bioenergy facilities from August 2010 to August 2011. The demand for biomass in the U.S. during this period grew by 38 %, with approximately 80 % of the production being used domestically, but it is expected that exports especially from the South will increase (Kittler, Price et al. 2012). The wood demand for 129 bioenergy projects within the region is expected to be about 47 million tons yr^{-1} by 2020.

The U.S. pellet industry is made up primarily of smaller plants with a capacity of less than 100,000 tons yr^{-1} relying predominantly on saw mill residues. The total capacity in 2010 is estimated to 5.9 million tons. Most recent data on pellet production suggests a capacity utilisation of 66 % (Cocchi, Nikolaisen et al. 2011). Most pellets plants are located in the eastern part of USA and projections suggests a development towards bigger plants with capacities up to 1 million tonnes yr^{-1} relying on wood chips or round wood from south-eastern U.S.

The U.S. is also among the 20 largest source countries contributing to the Danish wood pellet import, accounting for 2-6 % of the total import in 2009-2011 (Danmarks Statistik 2012). However, the U.S. does not contribute significantly to the Danish import of wood chips; due to transportation costs and phytosanitary restrictions, long distance transportation of wood chips for energy is limited compared to the long distance transport of pellets (Lamers, Junginger et al. 2012).

Industrial wood production has been fairly stable from 1990 to 2005 with a minor decline in the USA of -4 %. Wood fuel production has decreased significantly and has been approximately halved from 1990 to 2005. However, EU renewable energy policies seems to have reversed the trend, and a rapidly expanding segment of the bioenergy sector in the U.S. is pellet facilities shipping to Europe (Kittler, Price et al. 2012). In the short term, potentially more than 6 million tons of wood pellets will be bound for power plants in the United Kingdom from south-eastern U.S. in the next 5–10 years (Pinchot Institute 2010).

The feedstock for pellet production has traditionally been sawmill residues followed by wood chips and low grade round wood. The amount mill residues produced is estimated to 77 million dry tons, whereof 1.6 million tons are currently unused (Cocchi, Nikolaisen et al. 2011). A recent study by (Colnes, Doshi et al. 2012) focussing on south-eastern U.S., which is the most important region in relation to Danish U.S. sourced biomass. They judge that currently there resources are adequately available in this region to meet the demand, and it is expected that Denmark will continue to source biomass from this region. There are, however, potentially competition issues between domestic renewable energy policies and a growing overseas demand for wood pellets. If the wood industry continues to contract, the additional pulpwood feedstock and other low grade round wood sources may become available to the pellet industry (Figure 80).

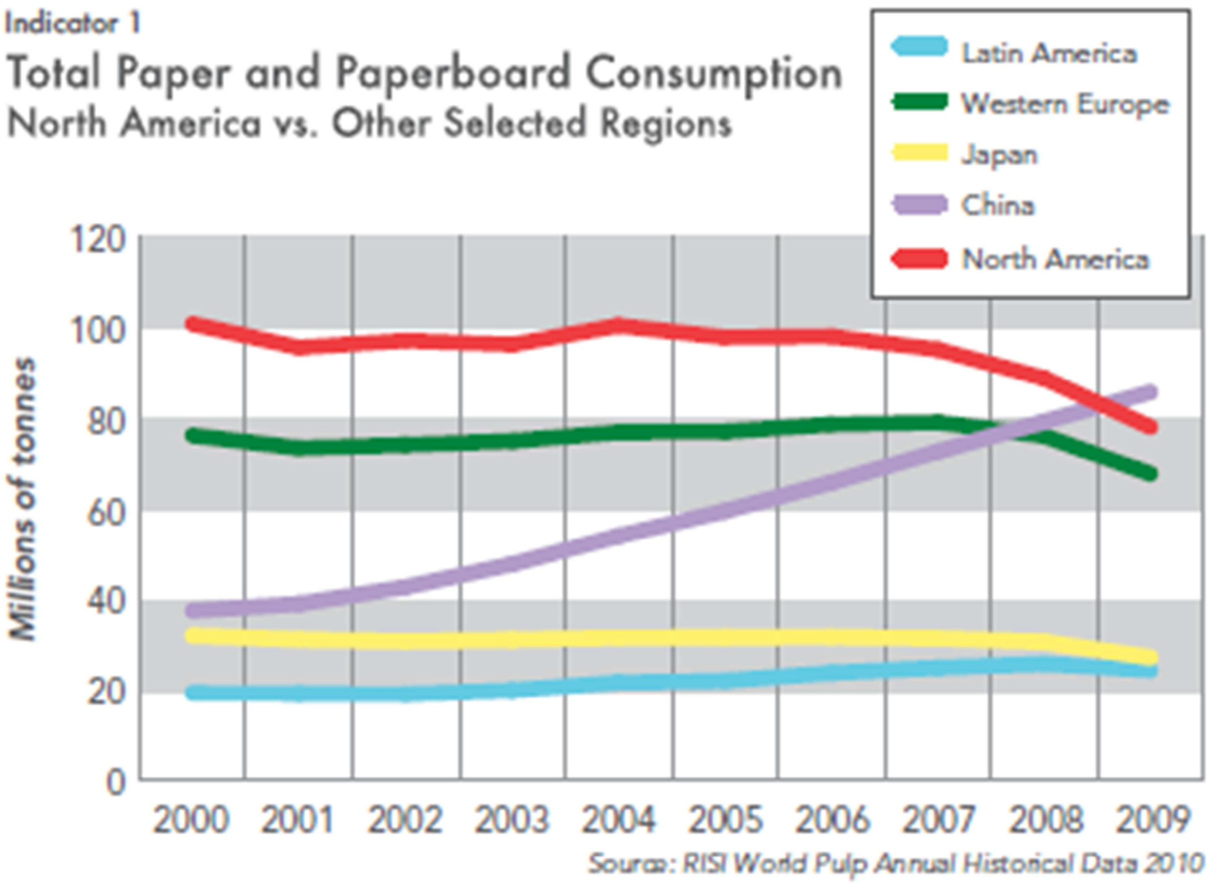


Figure 80. The total paper and paperboard consumption in different regions of the world (Environmental Paper Network 2011).

Part of the pulp and paper industry in the South is worried that increased pellet production in the area will lead to increased competition for wood. They reject that the pulp and paper industry in declining in the area, that only residues are used, and that the supply of wood is increasing in the South (Fledderman 2013). The pellet industry rather says it is not able to compete for resources with other wood industries and that it only exists where there is no competing pulp and paper industry in a distance of about 100 km (Meth 2013). The USDA has also found that the forest area is declining slightly in the region, for example due to urban development. However, the natural pine forest area has been declining rapidly since the 1950s, while the planted pine forest area has increased at a similar rate (Wear 2013). Forecasts also show that the area of planted pine forest will likely or is able to increase (Wear 2013). The pulp and paper industry is perhaps declining more in the north-eastern USA (Meth 2013), with less worry about competition for raw materials compared to the south-eastern USA. However, forest owners in both south- and north-eastern USA are probably welcoming new biomass demands and increased competition, with less control over the resource by one sector.

11.3.5. Wood resource potential

The updated billion ton study (U.S. Department of Energy 2011) estimate the sustainable US forest resource potentials to be approx. 47 million tons of dry matter yr^{-1} as logging residues and approx. 29 million tons yr^{-1} from thinnings; in total corresponding to approximately 1.4 EJ yr^{-1}. The 13-state south-eastern region (TX, OK, LA, AR, MS, TN, KY, AL, GA, FL, SC, NC, VA) is expected to see the greatest boom in biomass development over the coming years (Kittler, Price et al. 2012). The Southern Forest Futures Project of the USDA Forest Service forecasts that harvesting wood for energy in the south will increase between 54% and 113% by 2050, and a promising market can develop if the production can be managed in a sustainable way (Kittler, Price et al. 2012). The Great Lakes Region in north-eastern U.S. may also hold a considerable potential for production of wood biomass for energy, with the bioenergy development in western U.S. perhaps being restricted by concerns for forest health (Figure 81).

The potentials of this region are accompanied by the engagement of governmental and private actors in the mobilization and use of the resources. For example the Pellet Fuels Institute (PFI) joined the U.S. Department of Agriculture (USDA) and three additional biomass groups signed a memorandum of understanding (MOU) in September 2013 that shows a commitment by all parties to jointly grow and promote the wood to energy sector (http://biomassmagazine.com/articles/9430/usda-announces-initiative-to-expand-u-s-wood-to-energy-efforts/).

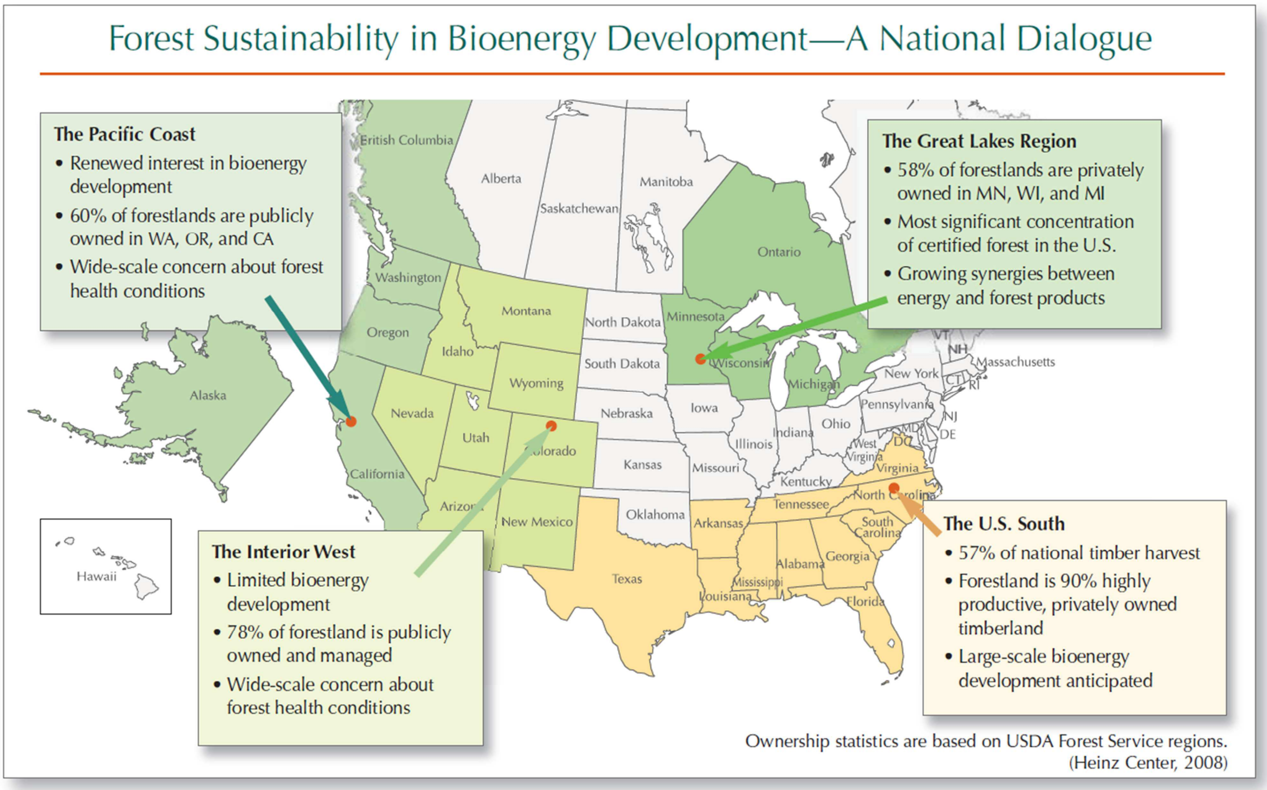


Figure 81. The bioenergy potential in different regions of the U.S. (Pinchot Institute 2010)

11.3.6. Challenges to sustainability

11.3.6.1. Forest area and standing stock

In the majority of wood producing regions of the U.S., the standing wood volume has been accumulating for decades, and the wood increment is generally larger than the wood harvest. During this period, agricultural lands have been abandoned and reverted to forests, while forestland has only been cleared for development of areas with high population growth (Kittler, Price et al. 2012). This has been a especially the case in the North Eastern U.S. (Butler and Ma 2011). (Kittler, Price et al. 2012) mention that many hold the perception that forest management and forest operations across the U.S. are sustainable, but that there are still issues to be aware of.

Even if the overall forest area has increased for some decades, it is worth noticing, that this trend followed from a period with dramatic decreases in the forest area in both southern and northern U.S. (Figure 82). Since the late 1700s, approx. 50% of the forest area in the North has been converted to non-forest land use. In the South, approx. 10% has been converted to forest plantations, while approx. 35% were converted to non-forest land uses. The increase in the forest area during the last decades has mainly taken place in the North, but has almost ceased to due urban expansion (Butler and Zhao 2011, USDA 2005). For some decades, the regeneration/afforestation with broadleaves has gone down, while the regeneration/afforestation with conifers, and to some extent mixed species composition, has gone up. The down going trend for broadleaves has maybe been reverted during the last years, but it is yet too early to say (Figure 82).

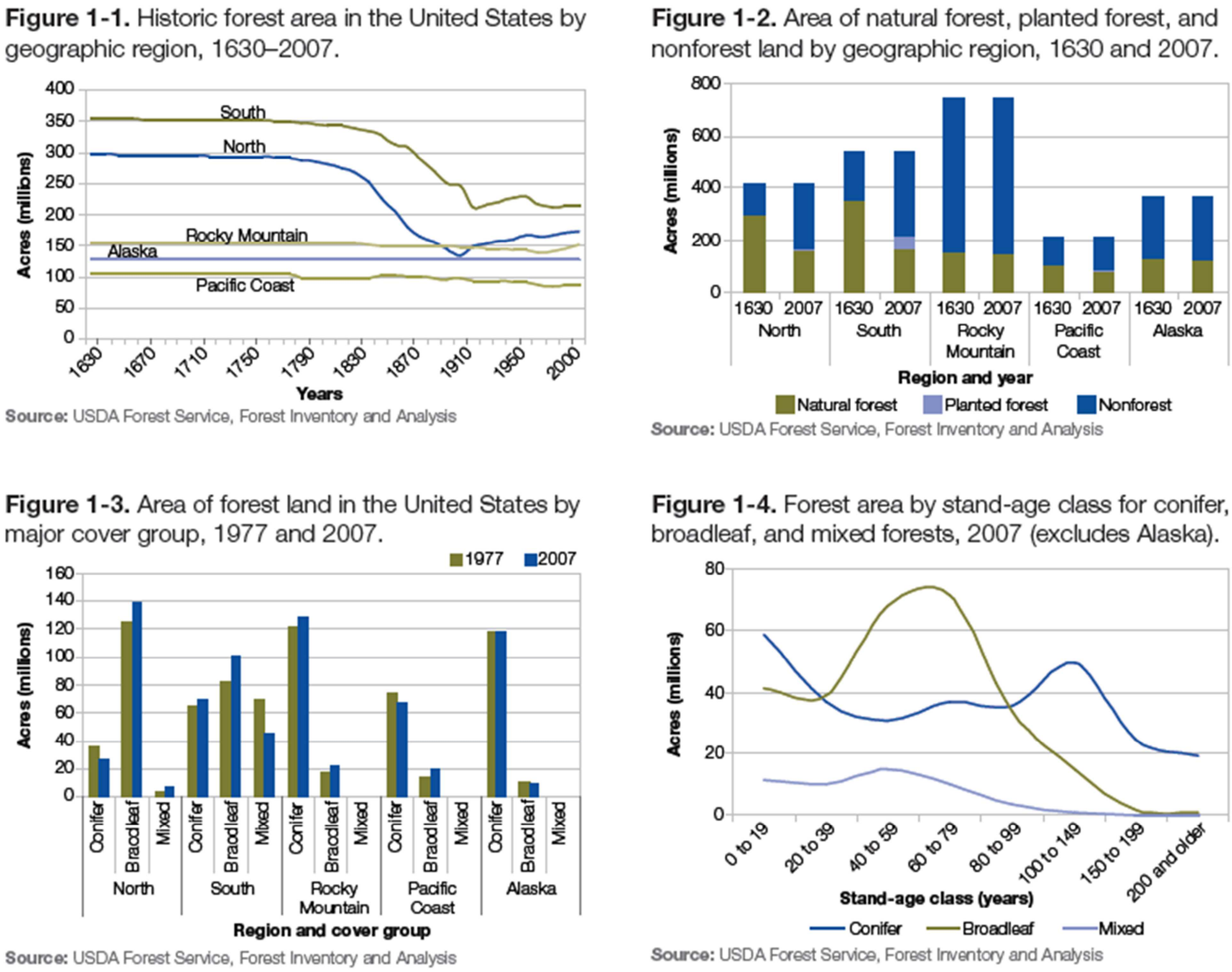


Figure 82. Developments in the forest area, forest conversion, and species composition (United States Department of Agriculture 2011).

11.3.6.2. Implementation of Sustainable Forest Management practices

In the U.S., states have promoted Sustainable Forest Management through educational outreach, educational institutions, non-governmental organizations and the forest products industry, with many private forest owners therefore having been exposed to Sustainable Forest Management approaches during some period (Kittler, Price et al. 2012). Developed Best Management Practices (BMPs) address especially maintenance and conservation of soil and water resources, and silvicultural issues related to site preparation for regeneration, application of pesticides and prescribed fire. Issues related to conservation of biological diversity are, however, rarely addressed by US BMPs (Kittler, Price et al. 2012), but measure have been taken at other levels. The U.S. does not have a dedicated “biodiversity plan”, but does have a long array of federal conservation statutes and programs to protect and use biological resources. The individual States have primary responsibility for fish, wildlife, habitat, and other “biodiversity” trusteeship duties (e.g., water rights) that are not otherwise covered by federal authorities (Snape III 2010).

Building on existing BMP programs, at least eleven states (MO, KY, MD, PA, ME, MI, WI, MN, MA, NH, VT) have also developed voluntary biomass harvesting guidelines to supplement BMPs (Kittler, Price et al. 2012, Stupak, Titus et al. 2013). The biomass harvesting guidelines typically include best management practices for protection soil fertility, wildlife habitat, water quality, and other values when harvesting forest biomass for energy. Regional guidelines have also been developed by the Forest Guild, which is a non-profit organization focused on ecological forestry. Such regional biomass harvesting guidelines have been developed for the Southeast, the Northeast, and the Pacific Northwest. The Southern Group of State Foresters has also developed biomass harvesting principles. The main focus of these specific forest biomass harvesting guidelines is the extent to which downed woody material should retained during biomass harvesting, with the purpose of maintaining soil fertility and to create habitat for wood living species (Kittler, Price et al. 2012). But also protection of rare ecosystems and sensitive sites is sometimes addressed, e.g. in the guidelines by the Forest Guild. Largely, the implementation of these new forest biomass guidelines is still to come.

11.3.6.3. Participation in international processes

The USA is participating in both the Montreal process and the GBEP partnership, which are other potential sources of information in relation to forest, biomass and bioenergy sustainability. A pilot testing of the GBEP indicators for the U.S. has been initiated, but no results are available yet. The Montreal process has only produced comparative studies with quite limited information, but the U.S. has produced national level reports in 2003 and 2010, respectively, on the sustainability of forests of the USA, using the Montreal SFM Criteria & Indicator framework. These national U.S. reports recognise the demand for energy wood as a pressing forest issue, that has the potential to mitigate climate change, but also may increase pressures on forested landscapes (United States Department of Agriculture 2011).

The criteria of the Montreal process are:

- Criterion 1. Conservation of Biological Diversity
- Criterion 2. Maintenance of Productive Capacity of Forest Ecosystems
- Criterion 3. Maintenance of Ecosystem Health and Vitality
- Criterion 4. Conservation and Maintenance of Soil and Water Resources
- Criterion 5. Maintenance of Forest Contribution to Global Carbon Cycles
- Criterion 6. Socioeconomic Benefits To Meet the Needs of Societies
- Criterion 7. Legal, Institutional and Policy Framework for Forest Conservation and Sustainable Management

A total of 64 indicators further specify the different criteria. The only indicator that directly addresses the use of forest biomass for bioenergy is “Avoided fossil fuel carbon emissions by using forest biomass for energy (5.24)”. For other indicators, the effects of bioenergy related practices are so far difficult to separate from practices related to wood production for other end-uses. However, the general status and trends may still be useful information for assessing the consequences of increasing the pressures on forests.

11.3.6.4. Soil, water and chemicals

Forested watersheds are important for provisioning of water for millions of people in the U.S. Historically; forest land has been cleared, thereby causing degradation of lakes and streams due to erosion and sedimentation. The use of waterways for logs transportation has also had detrimental effects in the past (USDA 2005).

Today, forest management has less impact on water quality than do agriculture and urban development (USDA 2005), but forestry operations are still responsible for approximately 10% of water quality impairments in the U.S., due to sedimentation associated with roads and stream crossings and the improper implementation of BMPs (Edwards and Stuart 2002, Kittler, Price et al. 2012). The educational outreach has therefore especially focused on the implementation of water BMPs (Kittler, Price et al. 2012). The use of fertiliser in forests is not allowed in North America (Titus, Thiffault et al. 2012), and such measures therefore have no influence on water and soil quality.

Various forest chemicals that have, however, been approved by federal, state and local governments as a silvicultural mean or to protect and maintain forest health (http://www.fs.fed.us/foresthealth/pesticide/). Pesticides are used to control of vegetation to favour growth of desirable species; to reduce fire fuel ; to keep on highways, utility, and railroad rights-of-way in forests clear of vegetation; in forest nurseries and riparian areas; and in site preparation before planting of trees. It is also used to suppress insects and diseases, and manage aquatic plants and fish. The use of chemical is quite common, and is also allowed by both the SFI and the FSC systems, even if they have criteria requiring minimization of their use (SFI 2012). Neary, Bush et al. (1993) review ten years of watershed-scale research on the fate of forestry-use pesticides in forested catchments under mainly operational conditions throughout the southern United States. The review included studies on application of chemicals such as hexazinone, picloram, sulfometuron methyl, metsulfuron methyl, azinphosmethyl, triclopyr, carbofuran, lindane, malathion, fenvalerate, copper-chromium-arsenic, and pentachlorophenol, and their off-site movement in stream flow, leaching to ground water, and to thermal combustion. They write as follows:

"Model verifications of pesticide fate and dissipation and risk analyses have been conducted using simulation models such as GLEAMS, CREAMS, and PRZM. Field study data indicate that movement is controlled by the main hydrologic pathways (e.g., surface runoff, infiltration, interflow, and leaching below the root zone). Peak residue concentrations tend to be low (< 500 µg/L), except where direct applications are made to perennial streams or to ephemeral channels, and where buffer strips are not used and do not persist for extended periods of time. Indirect effects noted from the use of pesticides in forested watersheds include temporarily increased nitrate nitrogen losses, reduced sediment yields, temporal changes in terrestrial invertebrate abundance, reduced plant diversity, and changes in particulate organic matter transport in streams. Very limited cumulative effects research has been conducted. The effects of increasing watershed size on herbicide concentrations and the impact of non-forestry pesticides on fish have been examined. Analyses conducted in regional environmental impact statements indicate that the low concentrations and short persistence of forestry pesticides in surface and ground water do not pose a significant risk to water quality, aquatic biota, or human health."

Another newer study from Texas also finds that risks of using herbicides are unlikely to degrade surface waters or lead to chronic exposure of aquatic biota (McBroom, Louch et al. 2013).

11.3.6.5. Biodiversity

A major sustainability challenge facing the south-eastern U.S. in relation to forests regards the protection of key habitats and associated species (NWF 2013). The forests in the South are among the most species rich in the U.S. (Figure 83), and many of these species are at risk, especially in private lands (Figure 84), as this land can readily change hands and competences build up through education and efforts to certify the land may be lost (Kittler, Price et al. 2012).

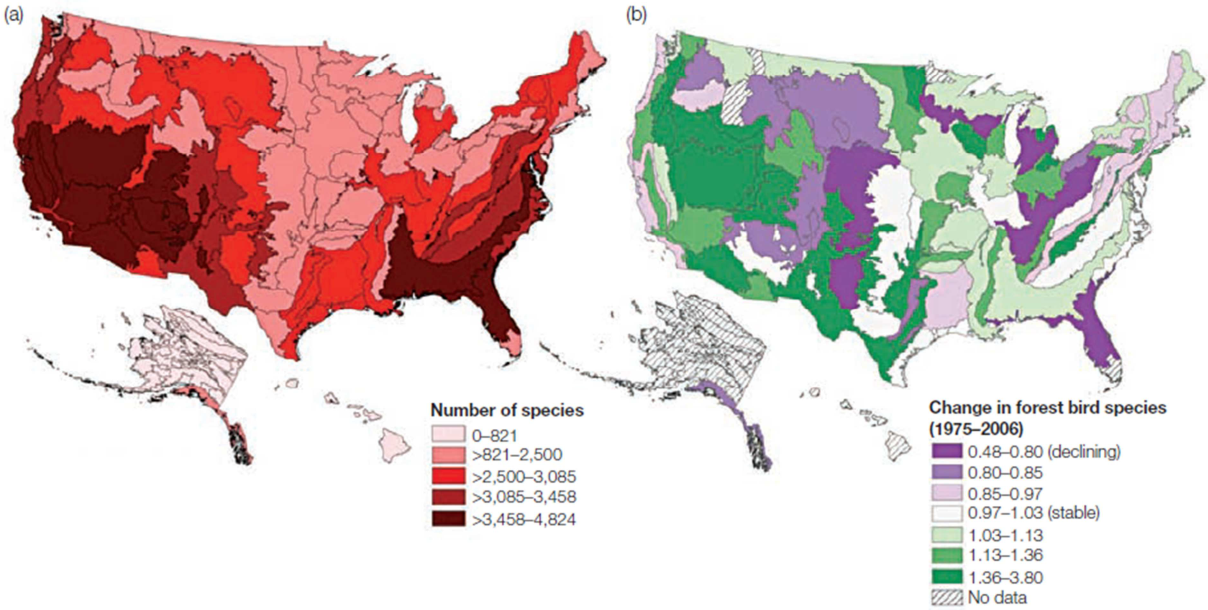


Figure 83. (a) Number of vascular plants and vertebrate species associated with forest habitats. (b) Estimated change in the number of forest-associated bird species from 1975 to 2006. Change is measures by the ratio of the 2006 species count estimate to the 1975 species count estimate. Values greater than 1 indicate increasing species counts (green shades). Values below 1 indicate declining species counts (purple shades). From United States Department of Agriculture (2011), figure 4-1.

Kittler, Price et al. (2012) suggest that part of the solution can be that biomass suppliers recognise lands of high conservation values, and support the protection of these. Markets that value forest can also help keeping forest land from being converted to other land uses. Furthermore, they see a need for continued support for implementation and development of sustainable forest management practice.

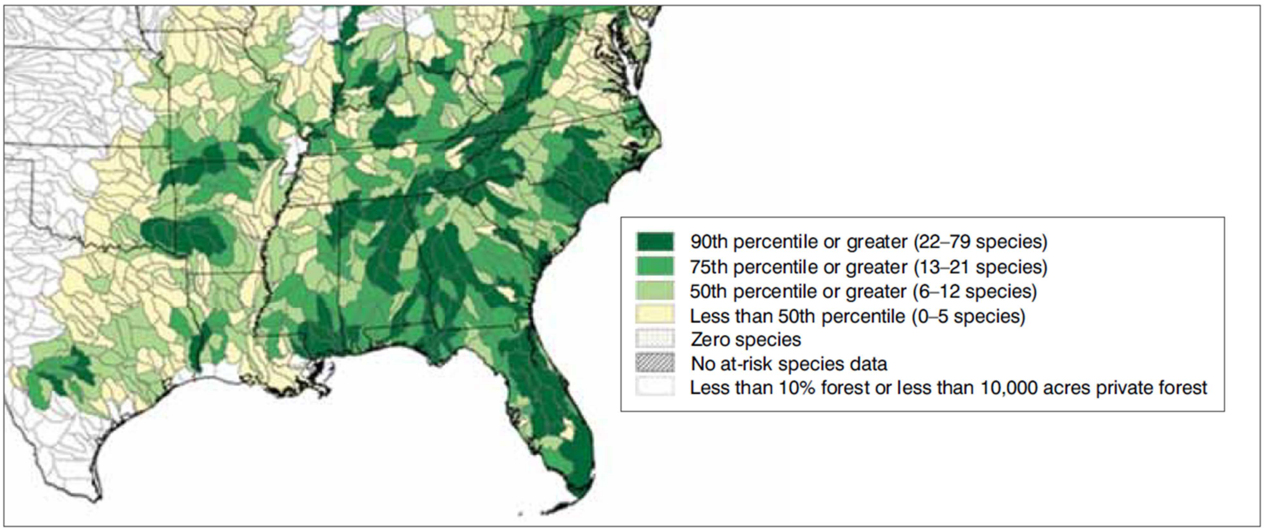


Figure 84.The number of at-risk species associated with private forest, by watershed in the south-eastern U.S. from (Kittler, Price et al. 2012).

In a recent case, the Enviva, the South's largest exporter of wood pellets, was heavily criticized in the media for sourcing wood for its pellet-manufacturing mill in Ahoskie, North Carolina, from clearcut wetland forests in the Mid-Atlantic Coastal eco-region (Natural Resources Defense Council and Dogwood Alliance 2013). They write that forested wetlands are in decline around the plant, and that they play a vital role as habitat for several species, also some which are in higher risk classes, and provide improved water quality, and buffer the water flow during drought. Enviva, on the other hand, stresses that they use harvesting equipment and practices that minimize environmental impacts, including the protection of soil and water quality (http://www.envivabiomass.com/faq-forests-fiber-sourcing/#wetlands).

In the South, there has also been concern over a possible large scale introduction of eucalypt and other fast growing species suitable for production of energy biomass. Modelling shows that for some of these bioenergy relevant species, there is a high risk that they will become invasive, including eucalypt species. Other species (*Saccharum*, *Sorghum*, and *Miscanthus*) show low risk, while other species require further evaluation, including one eucalypt species (Gordon, Tancig et al. 2011).

North-eastern States are generally less species rich than South-eastern (Figure 83). There is often a lack of especially historical data to determine the changes in species composition over time, but there are indications that forests in the northeast are among those with most extirpated forest associated species since 2003. Some states lost more than 100 species. Data also show, however, the presence of species that were not registered in 2003, even if maybe first of all due to more comprehensive registration methods being used in later registrations (United States Department of Agriculture 2011). Species' geographic distribution is dynamic, and it is being suggested that a statistically designed inventory would, over time, be the more suitable for showing consistent changes in biological diversity that are beyond 'normal' fluctuations (United States Department of Agriculture 2011).

Since the 1800s, US forests have been invaded by a large number of non-native plants, insects, and pathogens from Europe, Africa, and Asia (Figure 85). They are often pervasive and hard to manage, and in the worst case they may cause native species to become extinct (USDA 2005).

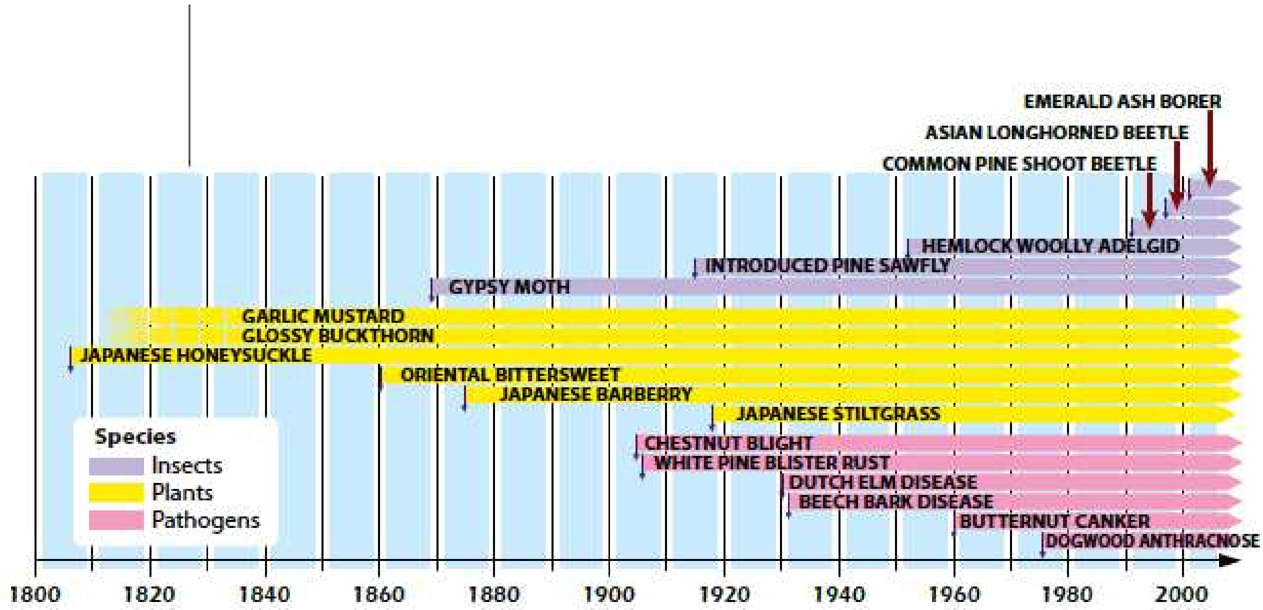
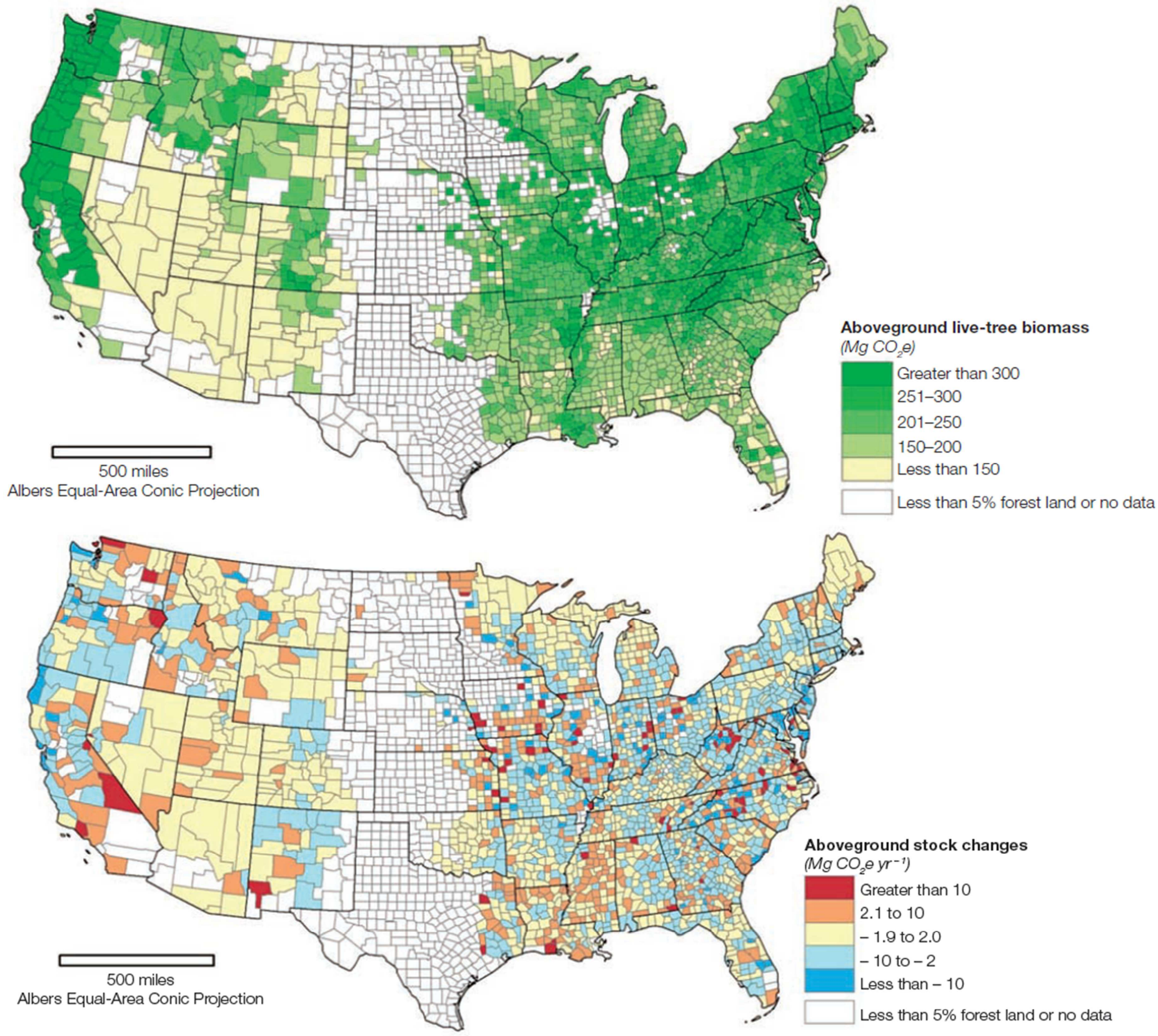


Figure 85. Timeline for introduction of invasive species in North-eastern U.S.

11.3.6.6. Carbon and greenhouse gasses

The U.S. monitoring shows that total forest ecosystem carbon stocks were maintained from 2003 to 2009, with positive increases from forest area expansion and growth (United States Department of Agriculture 2011). However, the size of the forest carbon pools differ among regions, as does the relative annual changes in the pools, with the individual regions experiencing increases and decreases (Figure 86).



Note: In conformance with IPCC reporting protocols, carbon sequuestration is denoted by negative numbers (blue) while carbon emissions to the atmosphere are represented by positive numbers (red).

Figure 86.Upper panel: Forest aboveground biomass stocks of living biomass by county of the U.S. 2006. Lower panel: Total forest ecosystem carbon stock annual flux by county in the U.S., 2006. Note that in conformance with IPCC reporting protocols, carbon sequestration is denoted by negative numbers (blue) while carbon emissions to the atmosphere are represented by positive numbers (red). (United States Department of Agriculture 2011).

Wood processing facilities often used wood-derived waste biomass for co-generation of electricity, and most of the electric utilities are therefore located near forests, including the West coast, Lake States, Northeast, and Southeast (United States Department of Agriculture 2011). Hundreds of electric utility plants use wood derived waste for power generation. The use of this biomass for energy is reported as avoided GHG emissions, with coal as a reference fuel. However, it can be discussed if these are truly avoided emissions, as there seem to be no conversion of coal-fired to biomass-fired plants. The amount of power produced from wood residue burning was a small fraction of the power produced by fossil fuel electric utility plants nationwide in 2007.

A study modeled carbon balances around 22 new plants proposed to be developed in southeastern USA (1014 MW and 3.05 million tons of pellet production) and 17 existing power in the same region (Carr 2013). They calculated a payback time of 53 years for this region, under these conditions. Biomass-based heat production or CPH applications are significantly more efficient compared to electricity plants, and would results in a shorter carbon payback period within the range of 5-10 years. However, such applications are less common in southeastern USA. They mention that the policy implications depend if the emphasis is on the short term and the existing of possible tipping points, or if it is on the long term accumulated carbon emissions, and are thus subject to the general tension that exist with regard to the climate benefits, see also section 8.2.

11.3.6.7. Air pollution

In the Clean Air Act, first adopted in 1970s, EPA sets limits on certain air pollutants and gives EPA the authority to limit emissions of air pollutants coming from sources like chemical plants, utilities, and steel mills (http://www.epa.gov/air/caa/index.html). Individual states or tribes may have stronger air pollution laws, but they are not allowed to have weaker pollution limits than those set by EPA. This act has contributed to significantly decreased emission of air pollutants through the last decades, even if there are still challenges, both in relation to human and ecosystems. The legislation is occasionally revised collaboration with stakeholders to address new issues or set stricter limits. However, wood fuel production does not seem to pose in additional challenges; they rather apply to the industry generally.

11.3.6.8. Competition with food production

Energy biomass production may compete with food production for land in the U.S. in the future. An optimization study analyzed the impact of CO_2 abatement policies, and showed that farm gate prices for all crops as well as animal products increase substantially, with simulated wheat prices for example for being 50–200% higher in 2050 (Johansson and Azar 2007). The increase in farm gate prices was not expected to cause shift in food consumption patterns, though, since the food price elasticity is low and the farm gate price is small relative to the retail price. The study by Johansson and Azar (2007) also suggest, that competition with food production will first of all occur when carbon taxes are low (US$20/t C), while for higher carbon taxes, plantations are also established on lower-yielding grazing land, that are not suitable for food production.

11.4. Canada

11.4.1. Forest types

Canada is dominated by four biomes: the boreal zone in the north, covering a major part of Canada as well as Alaska in the U.S.; the temperate coniferous forests zone in south western Canada, savannah and scrublands in the central part and temperate broadleaf and mixed forests in south-eastern Canada.

The areas with forests (87%), other wooded land (2%) and other land with trees (11%) cover 397.3 million ha corresponding to about 40% of the total land area (NRCAN 2012). Primary forest constitutes a large part of the forest area (53%), including areas of limited access in the North, while about 136 million ha (44 %) was naturally regenerated forest, and 9 million ha (3%) were planted forest (FAO 2010).

In Canada three classification systems are being used to describe the ecological framework conditions: Ecozones, forest regions (Figure 87), and plant hardiness zones. These classifications form a basis for national decisions about the forest management (http://cfs.nrcan.gc.ca/pages/125)

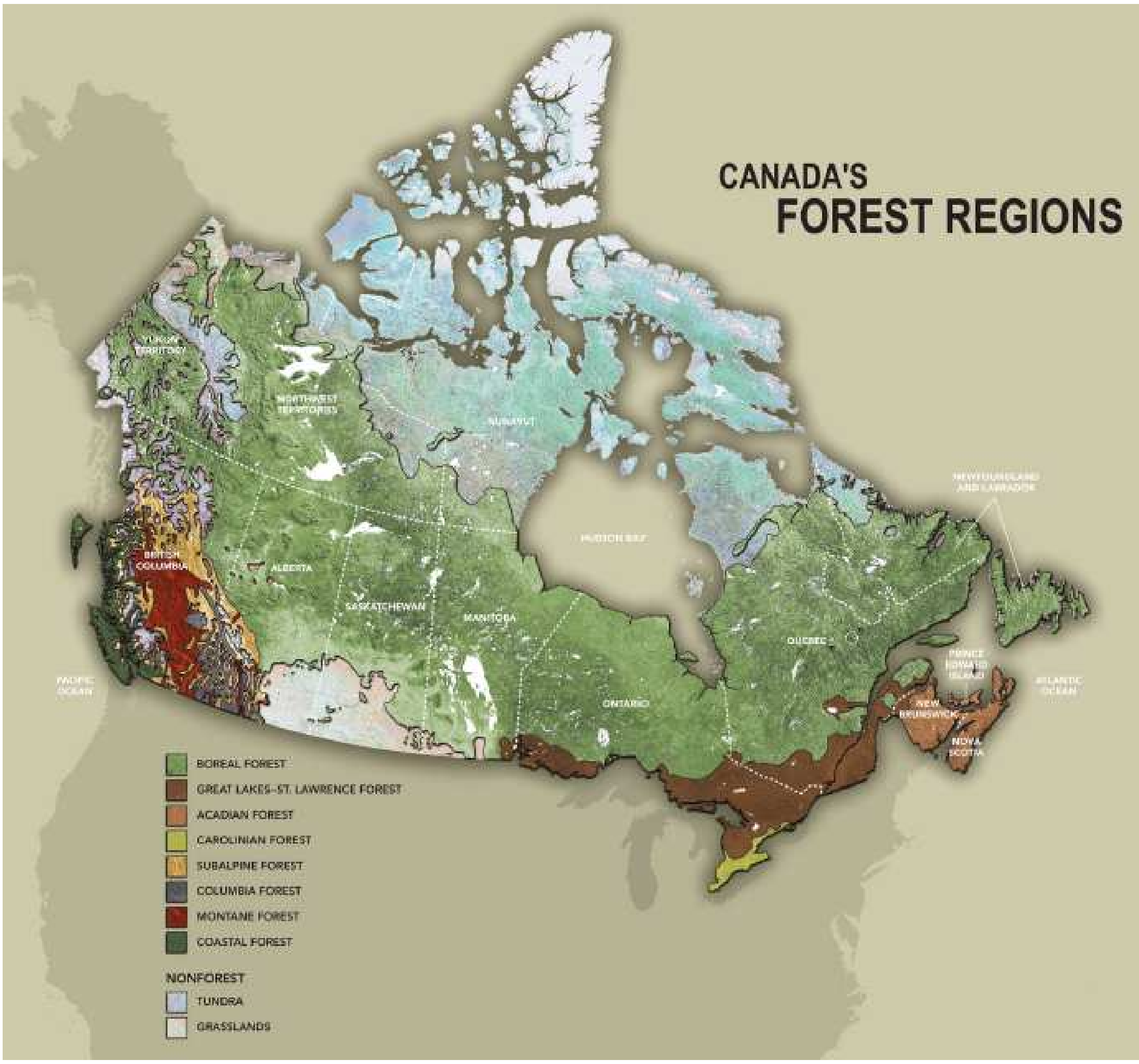


Figure 87. Canada's forest regions (http://cfs.nrcan.gc.ca/pages/125).

11.4.2. Forest ownership

The ownership structure in Canada is characterised by a large proportion of the forest being under public ownership, 93 %. Of these, 77% points are under the jurisdiction of the 10 provinces and 3 territories, and

16% points are under federal jurisdiction (FAO 2010, NRCAN 2012). Only 7% of the Canadian forests are privately owned. In for example Nova Scotia, New Brunswick and British Columbia, timber companies own large forest areas, while the rest of the private forest land is mainly owned by thousands of small family forest owners.

11.4.3. Forest management and governance

11.4.3.1. Forest management and legal status

Far the large part of the Canadian forests are permanent forest estate (FAO 2010), with a minor share having the status of protected forest (Table 36**Fejl! Henvisningskilde ikke fundet.**). About 230 million ha or about 66% of the forest land are under management (https://cfs.nrcan.gc.ca/). Canada did not report information to FAO about the size of the forest area that has a management plan (FAO 2010), but according to the Canadian Forest Service (CFS), forest management planning is "a rigorous, comprehensive and open process in all provinces and territories", which involves public participation and stakeholders consultations (https://cfs.nrcan.gc.ca/).

Table 36. Levels of protection of Canadian forests (FAO 2010).

	Permanent forest estate		Forest in protected area		Forest with management plan	
	1000 ha	%	1000 ha	%	1000 ha	%
Canada	285,587	92	24,859	8	-	-

The Canadian Forest Service provides an overview of the forest governance in Canada (https://cfs.nrcan.gc.ca/). It shows that Canada has a well-developed legal and policy framework on forests, and that national and sub-national forest policies are enacted. The provinces and territories have all developed and enforced legislation, regulations and policies related to forests (https://cfs.nrcan.gc.ca/). All forests are also subject to relevant national legislation, e.g. forests, such as the Species at Risk Act, the Fisheries Act and the Canadian Environmental Assessment Act, and international agreements that have been ratified by Canada (e.g. the Convention on Biological Diversity (CBD) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (https://cfs.nrcan.gc.ca/).

In the forests that are under provincial jurisdiction, different tenure arrangements are used to grant rights and responsibilities to companies operating in public forests. Before companies do any felling, they must develop a forest management plan, which should be approved by the provincial and territorial government. Based on the management plan the government issues harvesting permits. Failure to comply with management plans and harvesting permits can result in severe penalties, from fines or the suspension of harvesting authorities to seizure of timber and even imprisonment. The provincial and territorial jurisdictions closely monitor the activities of the companies operating in public forests, and require formal reporting on their activities (https://cfs.nrcan.gc.ca/). Systems of checks and controls are used to track the timber that is removed from the forest and government agencies conduct compliance audits. If there are signs of non-compliances, it will be investigated more thoroughly. If there is a violation, penalties may result and in serious cases it may be taken to court.

The federally owned forest is mainly located in national parks, lands owned by the Department of National Defence (DND), and First Nations reserve lands (https://cfs.nrcan.gc.ca/). Only relatively small volumes enter wood supply chains from these forests, but various federal government departments are responsible of regulation and management of operations in these forests. The legislation that applies to these lands are the Forestry Act and accompanying Timber Regulations, legislation enabling forest harvesting on reserve land and the relevant provincial and territorial legislation. Forest management plans are generally also required before operations can take place in these forests (https://cfs.nrcan.gc.ca/).

About one-seventh of wood harvested in Canada comes from private forests, which are governed under provincial/territorial and municipal regulations, guidelines and partnership programs (https://cfs.nrcan.gc.ca/). Some provinces have laws that set standards for forest management practices on private lands, and forest management plans are often used also in other provinces, where they sometimes use government programs as a model. Most provinces also have tracking mechanisms for timber from private lands, and land owners and local communities are often involved in monitoring of various forest values. Otherwise landowners are protected by general civic or commercial laws, which protects from trespass and theft (https://cfs.nrcan.gc.ca/).

It is currently being discussed and examined if Canadian provinces' existing policies, legislation and guidelines are adequate to ensure that forest biomass is harvested and used in a sustainable manner (Waito and Johnson 2010, Roach 2012). For all of the provinces, legislation and guidelines developed for conventional logging also apply to biomass harvesting. Such existing guidelines address especially riparian areas and soil disturbance. None of the Canadian provinces have specific forest biomass guidelines addressing all aspects of sustainable forest management, but to a varying level several provinces do address the issue in some manner, e.g. have specific biomass harvesting guidelines for soils and maintenance of site productivity (New Brunswick), rules about what can and cannot be removed from sites, policies on slash, regional regulation of biomass harvesting, review of the relevant issues on a site by site basis with instructions detailed in the Timber Sales Agreements and permits, or basics rules that whole-tree harvesting not permitted (Roach 2012).

Waito and Johnson (2010) likewise reviewed forest biomass harvesting guidelines in Canadian provinces and concluded that environmental concerns are increasingly discussed by all the ten assessed provinces. The general opinion is that the biomass harvesting must follow the existing forest management policies and guidelines, and that existing forest management guidelines are generally sufficient (see also (Berch, Bulmer et al. 2012). However, the need for monitoring of soil fertility is sometimes being discussed, and existing policies being revised.

Canada has ratified a number of supra national declarations and agreements including UNFCCC, UNCCD, ITTA, CITES, Ramsar, WHC, NLBI, CCD and CBD. Initially Canada ratified the Kyoto protocol in 2002 but decided to withdraw from the protocol with effect from 2012 (www.unfccc.int).

11.4.4. Certification

Canada has the largest forest certified area in the world (38% of the world's certified area), amounting to 148 million hectares in 2012. This is equal to 37% of the total forest area or 87% of the forests under management.

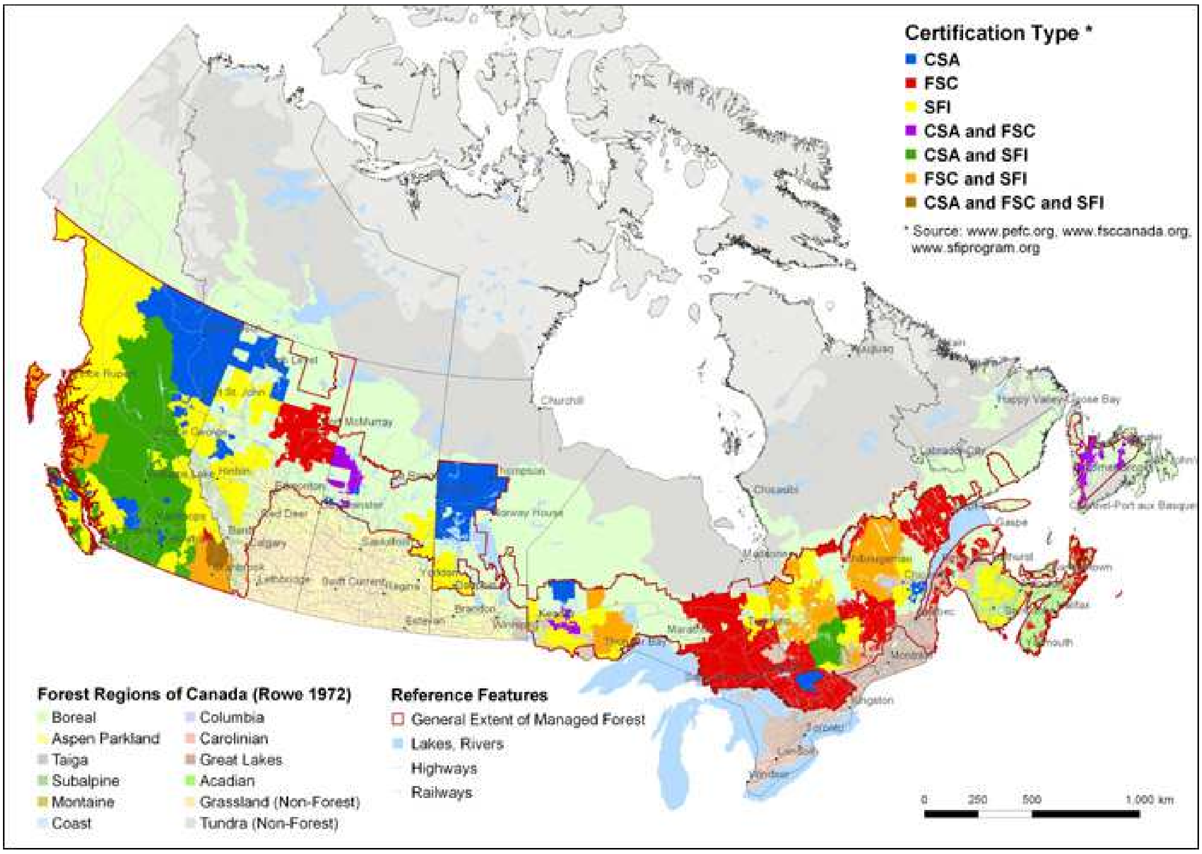


Figure 88. Certified forests areas in Canada by 2012, with 2013 corrections (http://www.certificationcanada.org/maps/).

The implemented schemes include SFI and CSA that are endorsed by PEFC, and FSC. The area of certified land has been stable during the last five years, but SFI and FSC increase their share of the certified area at the cost of CSA (Figure 88).

Figure 89. Area of certified forest in Canada, by certification system (http://www.certificationcanada.org/english/status_intentions/canada.php).

11.4.4.1. Implications for biomass trade

Possible new EU sustainability requirements for solid biomass would add another layer to the comprehensive governance framework that exists for forests in Canada, with the biomass entering the market along different 'sustainability pathways' (Figure 90).

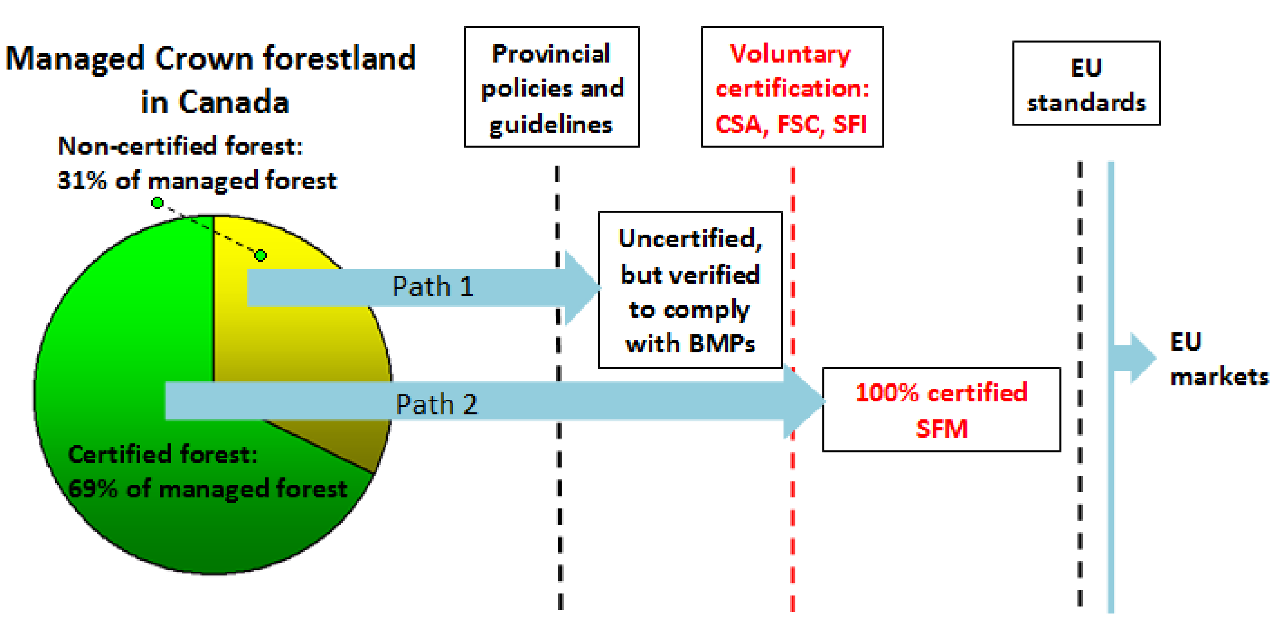


Figure 90. Multiple sustainability claims for Canadian exports to EU markets. Adapted from (Kittler, Price et al. 2012) by (Murray 2012). BMP: Best Management Practices.

With about 165 mill ha of Canadian forest being reported to the FAO under the category "primary forest" (FAO 2010), a critical issue for Canada is the EU recommendations for sustainability criteria for solid and gaseous biomass (European Commission 2010). These recommendations, which might become mandatory, exclude material from primary forest as an eligible source of biomass feedstock.

The problem is, among other, that in Canada 'primary forest' is not used as a category in forest and land-use inventories, but only as a category for carbon accounting and reporting ('managed' and 'unmanaged') These categories are socio-political constructs and are not meant to reflect a 'virgin' or protection status (IEA Bioenergy 2013). These areas may as such be either protected areas or part of the commercial forestry land base, where biodiversity is protected through sustainable forest management regulations and certification (IEA Bioenergy 2013). Another problem is that forest management in previous 'virgin' forest typically involves modification to a natural or semi-natural forest, but rarely plantation forest. It is also an issue that the prevalence of natural disturbances makes it hard to separate the boundaries between 'primary' forest and other forest types (IEA Bioenergy 2013).

The term 'primary forests' may useful to prevent land-use change in relation to production feedstock for liquid biofuels on agricultural land, but some argue that for forestry, the concept of 'sustainable forest management' (SFM), and measures of biodiversity and ecosystem functioning, as implemented in regulations, applies more properly to all forests (IEA Bioenergy 2013). It seems thus, that there is a great need for communication around future sustainability requirements and how to meet them.

11.4.5. Wood and wood fuel production

Industrial wood production has been fairly stable from 1990 to 2005 with an increase in Canada of 13% Wood fuel production has decreased significantly and has been more than halved from 1990 to 2005. However, EU renewable energy policies seems to reversed the trend, and a rapidly expanding segment of the bioenergy sector in the U.S. is pellet facilities shipping to Europe (Kittler, Price et al. 2012). In the short-term, potentially more than 6 million tons of wood pellets will be bound for power plants in the United Kingdom (UK) from the south eastern U.S. in the next 5–10 years (Pinchot Institute 2010).

The Canadian pellet production capacity in 2011 is estimated to 3.2 million tonnes, with more than half of the capacity located in British Columbia on the west coast (Cocchi, Nikolaisen et al. 2011). Production in 2011 is estimated to 2.1 million tonnes giving a capacity utilisation of 64%. Historically the Canadian pellet industry has relied on sawmill residues as feed stock. However, a sharp decline in building activities in USA in the last part of the 2000 has pushed the industry towards forest residues and dedicated energy forests as sources. Some plants source up to 70% of their feed stock from forest operations.

The prospects for the Canadian pellet industry are a significant increase in exports, but also an increase in domestic demands. The Canadian market for wood pellets is very limited and Europe is the main market receiving app. 60 % of the total production through ports in the Netherlands, UK and Belgium. USA is the second largest market for Canadian pellets.

11.4.6. Wood resource potential

The potential biomass resource in the form of roadside residues and residues from urban forests in Canada has been estimated in a review by Paré et al. (Paré, Bernier et al. 2011) to app. 0.45 EJ yr^{-1}. Due to the size of Canadian forests the amount of biomass available from forests killed or damaged by natural disturbances (fire, storm or insects) is considerable. Dymond et al. (Dymond, Titus et al. 2010) estimate a sustainable potential in 2020 to 51 ± 17 Tg yr^{-1} (~0.9 ± 0.3 EJ) of dry biomass from natural disturbances and 20 ± 0.6 Tg yr^{-1} (~0.36 ± 0.01 EJ) of dry biomass as clear cut residues. A significant fraction of the dead wood is located in the Western parts of Canada (British Columbia and Alberta), which may constrain the economic availability from a Danish point of view.

Insect killed forests are caused by two outbreaks; the spruce bud worm and the mountain pine beetle. The mountain pine beetle outbreak is centred in the montane cordillera ecozone in central British Columbia., but a certain amount of insect killed wood is also expected in Quebec (Dymond, Titus et al. 2010).

The biomass available after forest fires is also predominantly located in the western part of the country, but also with some potential from the boreal shield of Saskatchewan and Quebec.

While the production of wood industry residues has been fairly constant over the last 20 years at 17-21 M tons dry matter annually the available fraction has decreased significantly and is estimated to 2-5 M tons dry matter (Ackom, Mabee et al. 2010, Mabee and Saddler 2010).

In October 2012, a meeting was set up among European parties and the Canadian forest and wood fuel producing sector to resolve the matter. During 2013 another such meeting will be set up between market actors in the US and Europe to facilitate a dialogue on what is needed to establish supply chains that meet forthcoming European sustainability requirements.

11.4.7. Challenges to sustainability

11.4.7.1. Reporting of sustainability indicators

Canada is, like the USA, participating in both the Montreal process and the GBEP partnership, even if no pilot testing of GBEP indicators has yet been planned for Canada. The Montreal process has, as mentioned in the chapter for the U.S.A., only produced little comparative knowledge, but Canada has published annual national reports on since year 2000. These reports present results for a sample of the 46 indicators that Canada uses (NRCAN 2012). The Canadian criteria and indicator frame work has been developed and adopted by the Canadian Council of Forest Ministers (CCFM), with the 46 indicators being organized under six criteria:

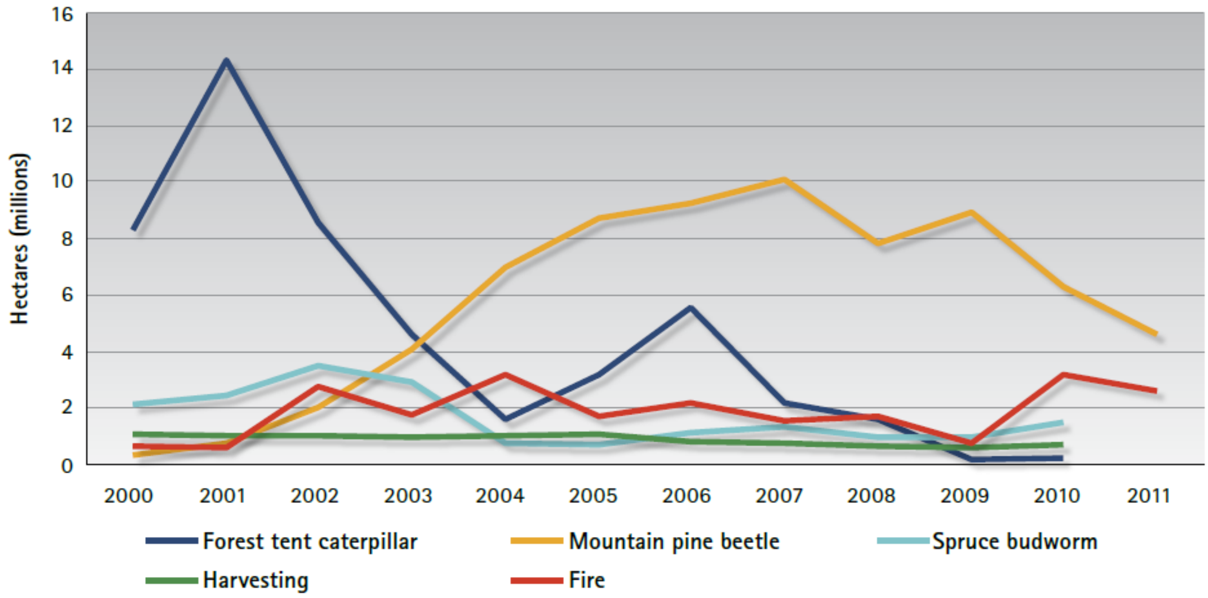
- CCFM Criterion 1: Biological Diversity
- CCFM Criterion 2: Ecosystem Condition and
- CCFM Criterion 3: Soil and Water
- CCFM Criterion 4: Role in Global Ecological Cycles
- CCFM Criterion 5: Economic and Social Benefits
- CCFM Criterion 6: Society's Responsibility

All criteria are relevant to forest bioenergy, but do not address the issue directly.

11.4.7.2. Forest area and standing stock

The forest area is relatively stable in Canada, but is nevertheless decreasing (https://cfs.nrcan.gc.ca/). The deforestation rate has been decreasing during the last decade from 64,400 ha yr^{-1} in 1990 (0.016% yr^{-1}) to 44,800 ha yr^{-1} in 2010 (0.011% yr^{-1}). The cause is first of all conversion to agricultural land (19,100 ha year in 2010), which is, however, only half of what it was in 1990. Land conversion due to oil and gas extraction has doubled during the period (now 10,600 ha yr^{-1} in 2010), and rate of conversion due to urban expansion has also increased a little (4,600 ha yr^{-1} in 2010). The conversion rate due to establishing permanent access roads in forest is about 4,500 ha yr^{-1}. Afforestation is negligible.

Coniferous forests account for 67% of all forest land (about 234.7 million hectares), mixedwood forests 16% (about 55 million hectares) and broadleaf forests 11% (about 37.7 million hectares) (https://cfs.nrcan.gc.ca/). The dominant age class of the coniferous forests is 81–120 years, while it is 41–80 years for the broadleaf and mixedwood forests. The dominance of the young age classes in two of the 15 Canadian ecozones, the Atlantic Maritime and Mixedwood Plains, is most often due to the forest regenerating forest after harvesting. The dominance of the oldest age-class category (161+ years) in the temperate rain forests of the west coast is due to natural stand-replacing fires being rare. The oldest forests in the Boreal and Taiga ecozones is generally in the 81-120 years category, which reflects that wildfire is more common in these forests. The forest is also sometimes disturbed by insects and pathogens over large areas (Figure 91). The age class distribution is as such determined by the cycles of disturbance and renewal (https://cfs.nrcan.gc.ca/).



Source: Canadian Interagency Forest Fire Centre, National Forestry Database and British Columbia Ministry of Forests, Lands and Natural Resource Operations

Figure 91. Area of forest distrubed annually in Canada, by cause, in 2000-2011 (NRC 2012).

11.4.7.3. Soil, water and pesticides

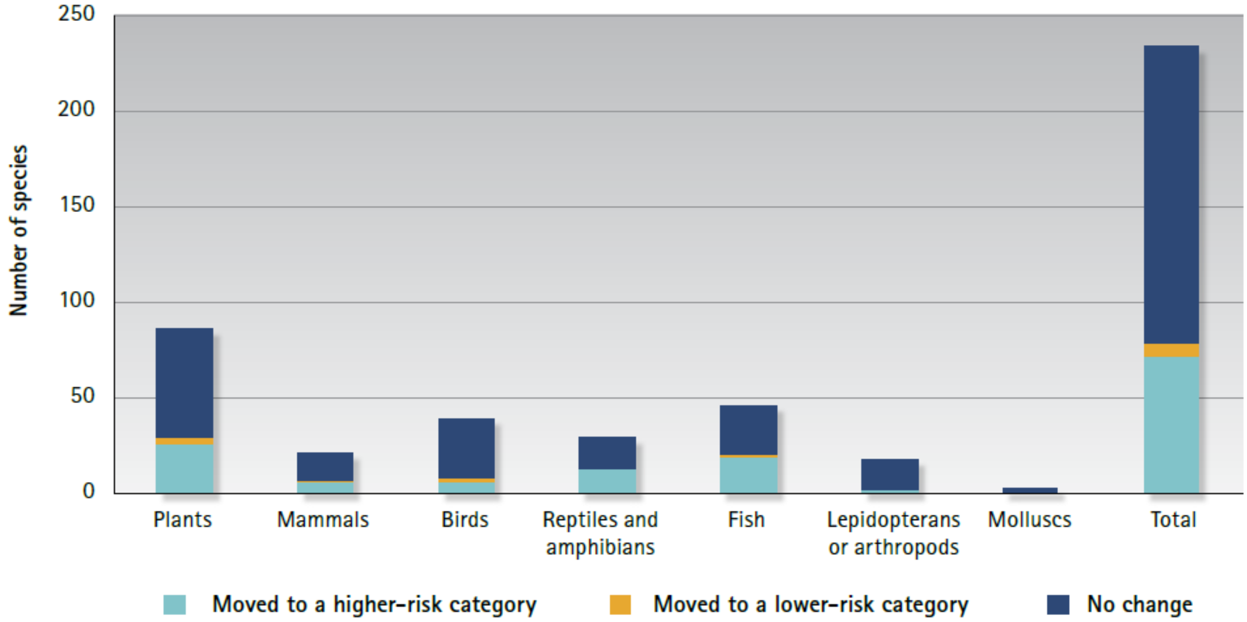
Canada is currently carrying out research to further examine the cumulative effects on long-term soil quality and biodiversity of removing increased amounts of organic matter from the forest during harvesting (https://cfs.nrcan.gc.ca/). Some results already exist, and lately a large review was published, which showed very variable effects of biomass harvesting on various soil parameters in the boreal and temperate zone (Thiffault et al. 2011). This emphasizes the need for site specific evaluation and guidelines.

Research on the effects of different biomass harvesting intensities on water quality and quantity was initiated in 1997 in the Turkey Lakes Watershed north of Sault Ste. Marie, Ontario (https://cfs.nrcan.gc.ca/). In this experimental site, data on stream and lake chemistry, hydrology, and soil chemistry etc. have been gathered 30 years, and the site as such has comprehensive data that shows the situation before the harvesting.

It is not allowed to use fertilizer in Canadian forests (Titus, Thiffault et al. 2012), while herbicide application to enhance regeneration success and maximize growth is used, as well as application of insecticides to control defoliating insects such as spruce budworm. In many cases, control is also made through appropriate silvicultural or stand management techniques.

11.4.7.4. Biodiversity

In Canada, the Committee of the Status of the Endangered Wildlife in Canada (COSEWIC) each year assesses the status of species that are thought to be at risk at some level (NRCAN 2012). There are more species that have moved to a higher risk category, than species that have moved to a lower category (Figure 92). The reasons are various, for example habitat loss, degradation, climate change, pollution, overfishing and hunting. In the North, the impact on bears of increasing natural resource extraction is a concern. It is uncertain to which extent increased biomass harvesting would influence the habitats of these species in different type of forests.



Source: Committee on Status of Endangered Wildlife in Canada

Figure 92. Change in the statues of forest associated species at risk, 1999-2012.

11.4.7.5. Carbon

The amount of carbon stored in Canadian forests has decreased slightly during the last 20 years from 14.3 billion tons to 13.9 billion tons (1990-2010), which is a decreased of about 3%. These amounts do not take account of all forests, but only of about 230 ha classified as managed forest according to the UNFCCC guidelines (FAO 2010). It is, however, difficult to say if there is an overall trend due to a large annual variation, due to wildfires and, during the last decade, especially insect damages (Figure 93). The magnitude of the fluctuation is about +/- 100 million tons of CO_2eq, while the total stores of carbon in 2010 corresponded to about 51,000 million tons of CO_2eq.

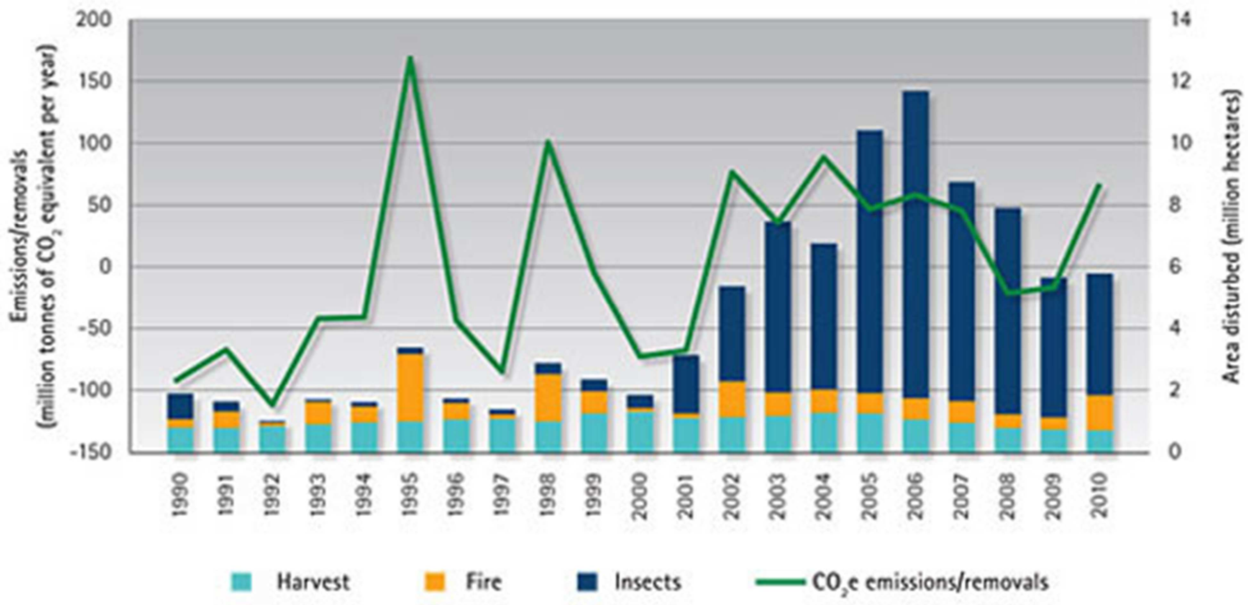


Figure 93. Carbon emissions/removals in Canada's managed forests, 1990-2010.

11.5. South America

11.5.1. Forest types

South America is characterized by tropical and sub-tropical moist broadleaf forests in the north, grasslands and savannah in the central part and temperate grasslands in the south. Furthermore there is a stretch of temperate broadleaf and mixed forests in the south-west.

The Brazilian territory alone makes up 48 % of the land area in South America and 60 % of the forest area.

The total forested area in 2010 is 864 million ha of which 520 million ha are found in Brazil. The South American forest area has decreased steadily since 1990 with 4.1 million ha annually on average. Forest conversion rates were slightly higher from 1990 to 2000 and lower from 2000 to 2010. In absolute terms Brazil has lost most forest area, 55 million ha, between 1990 and 2000. In relative terms the highest conversion rates are seen in Ecuador, Paraguay and Argentina (FAO 2010). In Uruguay the opposite development is seen. The country has almost doubled its forest area from 920,000 ha in 1990 to 1,744,000 ha in 2010.

In total 624 million ha (72 %) was classified as primary forest in 2010, 180 million as naturally regenerated forest and 14 million as planted forest. There are however huge differences between individual countries. In Brazil, French Guiana and Surinam more than 90 % of their forest area is classified as primary. Argentina, Columbia and Paraguay have a high proportion of forest managed through natural regeneration and Uruguay has comparatively large areas of planted forest (Figure 94).

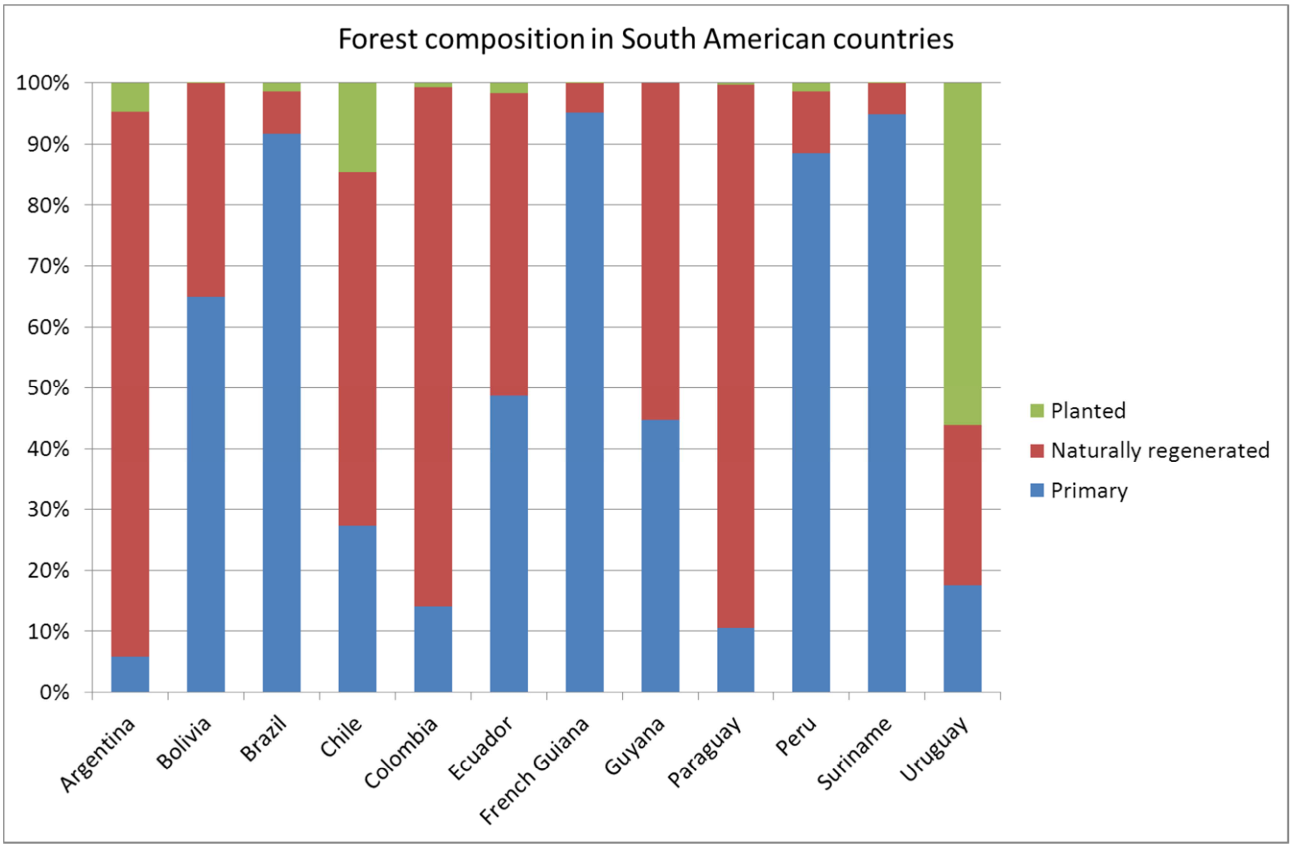


Figure 94. The relative distribution of the forest area to primary forests, naturally regenerated forests and planted forest in South American countries.

11.5.2. Forest ownership

The ownership structure of South American forests varies between countries. Public ownership is predominant in countries with large forest areas and as such a major part of South American forests are in public ownership (Table 37).

Table 37. Forest ownership structure in South American countries (FAO 2010).

	Public	Private	Other
	%	%	%
Bolivia	100	n.s.	0
Brazil	81	19	0
Chile	25	75	0
Columbia	22	67	11
Ecuador	15	2	83
French Guiana	100	n.s.	0
Guyana	80	20	0
Paraguay	39	61	0
Peru	62	18	20
Suriname	99	1	0
Uruguay	1	99	0
Venezuela	100	0	0

11.5.3. Legal and political framework

About 90% of the forest area in South America is covered by a National Forest Programme, and all countries except one forest legislation (FAO 2010). Except for Peru, however, only a small part of the forest area is covered by a forest management plan (Table 38), which may partly be because of the large area (>70%) with primary forest, i.e. forest of native species with no indications of forest management activities taking place. The size of the protected area varies between countries, from 4-30%, with the largest forest and protected areas in Brazil and Bolivia.

Table 38. Levels of protection of South American forests (FAO 2010).

	Permanent forest estate		Forest in protected area		Forest with management plan	
	1000 ha	%	1000 ha	%	1000 ha	%
Argentina	-	-	1,160	4	-	-
Bolivia	38,611	68	10,680	19	10,400	18
Brazil	242,986	47	89,541	17	30,543	6
Chile	13,634	84	3,992	25	2	n.s.
Columbia	-	-	-	-	-	-
Ecuador	9,221	93	-	-	-	-
French Guiana	6,598	82	2,418	30	2,222	27
Guyana	12,222	80	-	-	5,525	36
Peru	18,821	28	-	-	61,427	90
Suriname	6,689	45	2,015	14	-	-
Uruguay	752	43	-	-	-	-

Most countries in Latin America have, since the UN conference in Rio in 1992, made comprehensive revision to their forest laws in order to combat deforestation and ensure a more sustainable forest management. Their forest legislation is generally rigorous and comprehensive (Uruguay expected) with strict thresholds for environmental, economic and social issues, even if there is generally a significant gap between rules and their implementation (McGinley, Alvarado et al. 2012). Most countries' forest are regulated at the national level, while Argentina and Brazil have a federal system with national laws setting, while sub-national jurisdictions implement the laws and maybe additional laws (McGinley, Alvarado et al. 2012).

Brazil's first Forest Code was approved already in 1934, with amendments decided in 1965 (Banerjee, Macpherson et al. 2009, Walter 2013). It stipulated protection of large forest areas on the Amazon, and require that landowners keep a portion of their land forested, 80% in the Amazon forest; 35% in the Cerrado region; 20% in other regions (Legal Reserves) and that Permanent Protected Areas (APPs, in Portuguese: riparian areas, areas around lakes, slopes and tops of hills and mountains, etc.) be protected. The law is considered expensive by farmers, and they have been breaking the law for year, thus being in an illegal position. The laws enforcement was weak and the government did not offer incentives for compliance. In spring 2012, a proposal for relaxing the requirements of the Forest Code was passed by the Brazilian Congress. The proposed law reduce the Amazon minimum Legal Reserve forests from 80% to 50% and also allow farmers to cut down trees closer to riverbanks, with increased soil vulnerability to soil erosion as a consequence. Brazilian President Dilma Rousseff vetoed 12 articles of the law and issued a provisionary law to replace them. The minimum Legal Reserve in the Amazon will be changed to 50%, but the provisionary law only enable past offenders to escape fines if they meet a set of minimum reforestation standards. The provisionary law also clarifies minimum reforestation standards for small holders, which were unclear the proposal that was passed by the Congress. Finally, offenders will be cut off access to rural credits if they fail to reforest illegally deforested areas within five years of publication of the law (BBC, 25 May 2012: http://www.bbc.co.uk/news/world-latin-america-18213892, Bloomberg Businessweek News, 19 Oct 2012: http://www.businessweek.com/ap/2012-10-19/brazils-president-line-vetoes-new-forest-code,

Börner, 12 June 2012: http://blog.cifor.org/9514/amid-brazil-forest-code-controversy-will-presidential-vetoes-benefit-forests/, (Walter 2013)). In addition to this, the Legal Land Right Program, passed in 2009, aim to settle land tenure rights in the region, e.g. for settlers that were attracted to the Amazon by official and private settlement projects in the early 1970s (SSC 2010). It has been criticized that the law will not discourage wealthy landowners from holding onto unproductive land that could provide landless families access to important legal rights, and in this manner also protect the Amazon from deforestation (Thomas 2012).

The Forest Code applies only to private land, but in 2006, Brazil's first Public Forest Management Law (PFML) was approved. More than 80% of the forested land in the Amazon belongs to government, but until this law as passed, there had been little attempt to implement Sustainable forest management on these lands. The law sets an approach for forest concessions to be allocated through a bidding process. The contracts will run over 40-year contracts, with requirements that trees are logging under a sustainable development plan. The law stipulates that 20% of all revenues will go to the Brazilian Forest Service (BFS), the Brazilian Institute of Environment and Renewable Resources (IBAMA). Most of the illegal land occupation is on federal land, and it is believed that the law will create support a legal forest industry, employment and better conditions for local communities. The area of land that will be affected by the law in the short to medium term is likely to be rather small, in the range of 1-11 million ha, but the law gives possibility for development that is consistent with forest conservation goals, and makes agriculture not the only alternative for regional development in the Brazilian Amazon (http://wwf.panda.org/?63140/New-forest-law-in-Brazil-helps-save-the-Amazon, (Tomaselli and Sarre 2005)). The first concessions have only just been given (Alves 2012), (Figure 95) and there is, as such, still no experiences with the actual effects of the law.

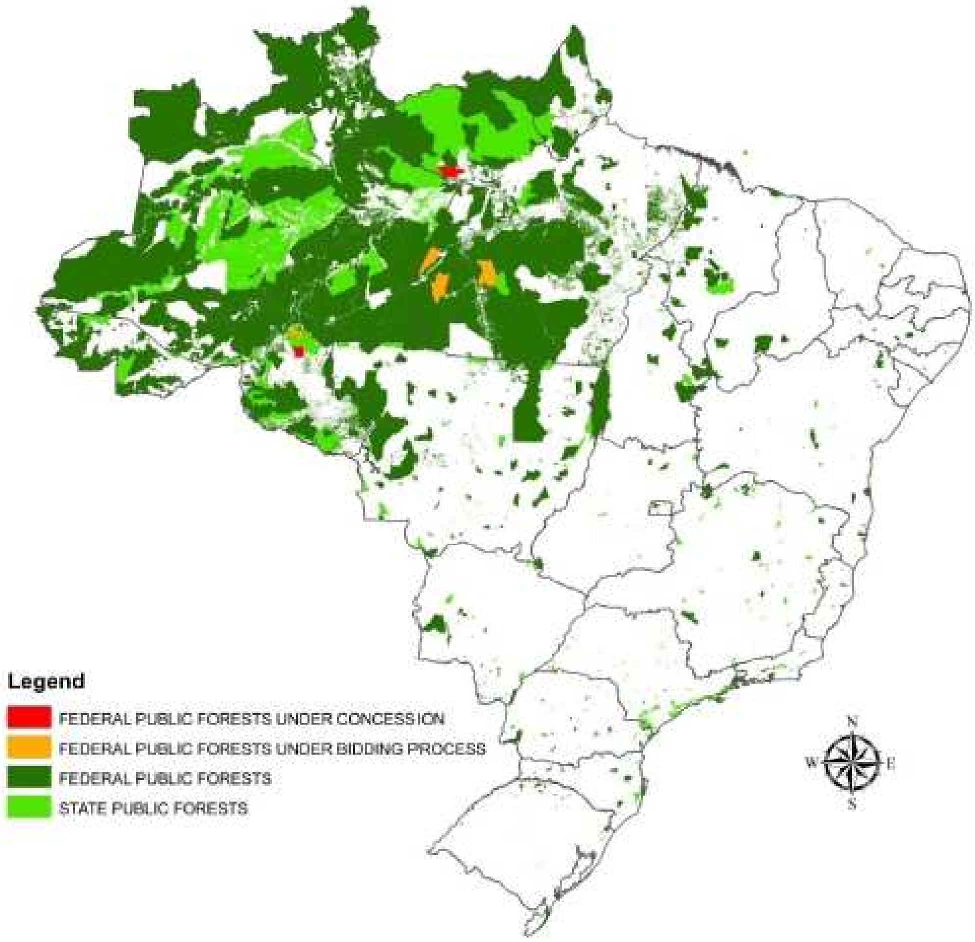


Figure 95. Status of the concessions in the Amazon under Brazil's Public Forest Management Law (PFML)(Alves 2012).

Another regulation is the Brazilian agroecological zoning legislation for sugarcane and palm. It forbids sugarcane cultivation on slopes of more 12% declivity, in the entire Amazon region (59% of the country) including previously deforested areas, areas with any kind of natural vegetation (to prohibit new deforestation), the Pantanal wetland and its hydrographic basin, and all high conservation-value areas (however, not on the Brazilian savannah, the Cerrado) (Leopold 2010). Apart from this, the soy producing companies made pledge not acquire soybeans from areas the Amazon which has been deforested since July 2006 (the Soy Moratorium) (Walter 2013).

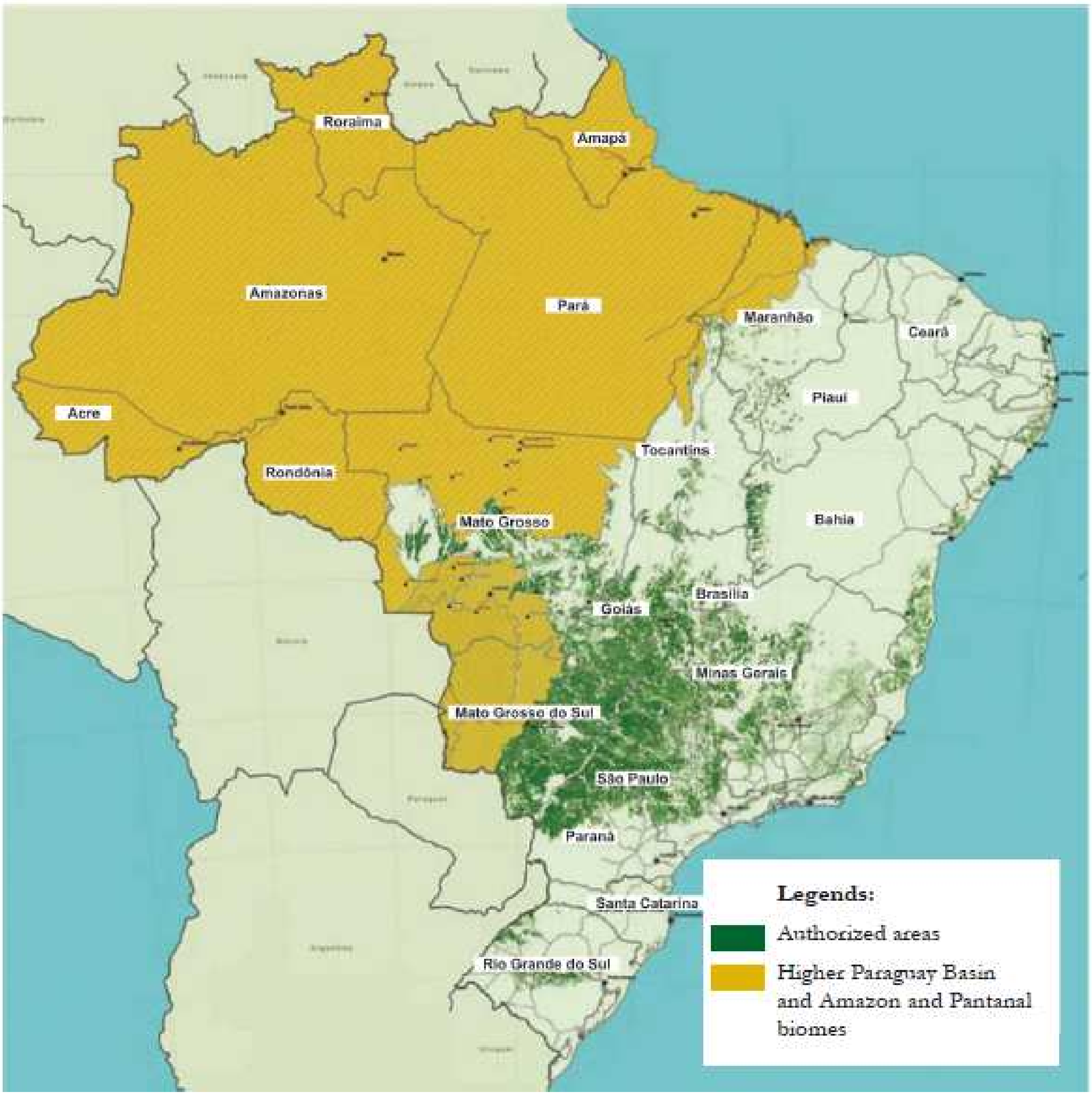


Figure 96. Agro-ecological sugarcane zoning in Brazil (SSC 2010).

The South American countries have ratified the international conventions and agreements relevant to forestry as most other countries. The CBD, UNFCCC, Kyoto Protocol, UNCCD, CITES, Ramsar, WHC, and NLBI are ratified by all countries except the Falkland Islands and French Guiana. ITTA is also ratified by most countries except Argentina, Chile, Paraguay and Uruguay.

11.5.4. Certification

Only a very small part of the forest area in South America is certified according to either FSC or one of the PEFC endorsed systems, Cerflor in Brazil and Certflor in Chile.

Table 39. Total forest area and certified forest area in South America (FSC 2012, PEFC 2012). Some areas may be double certified.

	Total forest area		Forest area certified by FSC		Forest area certified by PEFC	
	1000 ha	%	1000 ha	%	1000 ha	%
Argentina	29,400	11	305	1	0	0
Bolivia	57,196	53	1,272	2	0	0
Brazil	519,522	62	7,204	1	1,225	0.2
Chile	16,231	22	508	3	1,914	12
Columbia	60,499	55	94	0.2	0	0
Ecuador	9,865	36	54	0.5	0	0
French Guiana	8,082	98	0	0	0	0
Guyana	15,205	77	0	0	0	0
Peru	67,992	53	818	1	0	0
Suriname	14,758	95	89	0.6	0	0
Uruguay	1,744	10	826	47	0	0
Venezuela	46,275	52	140	0.3	0	0

Purbawiyatna and Simula (Purbawiyatna and Simula 2008) state that there is general consensus in Brazil that certified forest operations fulfill legal requirements and are in line with national forest policies and, for this reason, certified companies there are subject to fewer governmental audits. This is similar to also the case in Bolivia, where there is a high compatibility between legislation and the requirements of forest certification (Contreras-Hermosilla and Ríos 2002).

11.5.5. Wood and wood fuel production

In 2010 Brazilian industrial wood production made up 65 % of the total South American production, and, obviously, changes in the Brazilian production greatly affect the total production. The Brazilian production of industrial wood has been fairly stable, with a drop in 2000 and a slight increase towards 2010. Regarding wood fuels, the production declined significantly from 1990 to 2000 and has been stable on the year 2000 level since. The residential use of fuel wood has declined, but at the same time the production and use of charcoal for industrial applications have increased. The industry accounts for 90% of the charcoal consumption, with pig-iron production accounting for two thirds of this (FAO 2010).

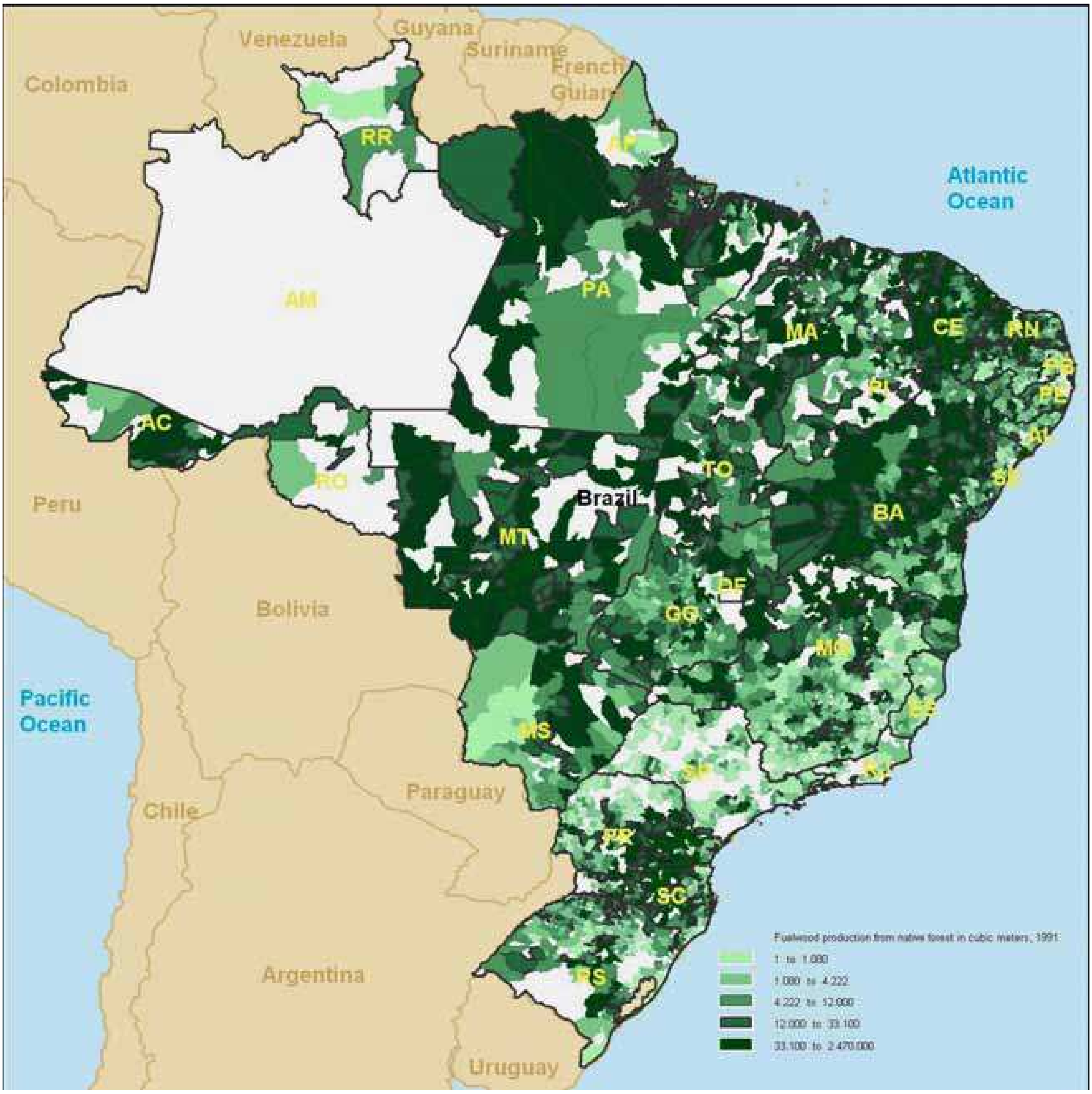


Figure 97. Fuel wood production from native forest, municipal district level, 1991 (Nogueira, Coelho et al. 2009).

The wood used for charcoal production is increasingly sourced from forest plantations rather than native forests. In 1990, 60% of Brazilian charcoal production was from native forests and 40% from plantations but (Figure 97 and Figure 98), but by 2008, the corresponding figures were 36% and 64% (FAO 2010). The 5.4 million hectares of forest plantations (2005) also supplies feedstock for the pulp and paper industry.

In Chile, Peru and Uruguay industrial wood production has more than doubled since 1990 and in Columbia and Ecuador has more than halved in the same period.

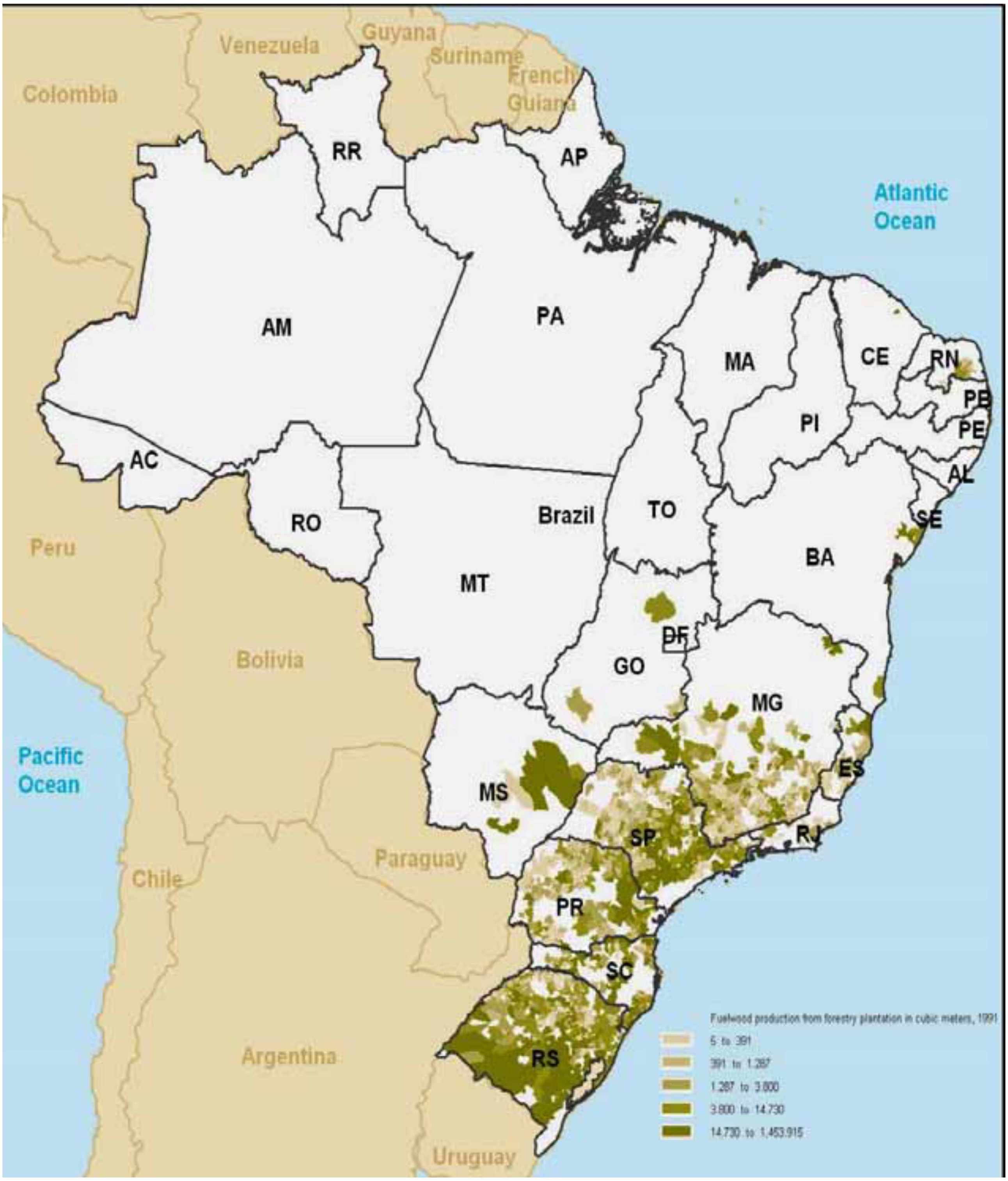


Figure 98. Fuel wood production from forest plantations, municipal district level, 1991 (Nogueira, Coelho et al. 2009).

Brazil also has the largest wood pellet production capacity in South America, but compared to some of the other regions described in this report it is currently not very large. (Cocchi, Nikolaisen et al. 2011) report the capacity to about 320,000 tonnes annually. In Chile perhaps two plants are in operation with a limited capacity and a limited market (Cocchi, Nikolaisen et al. 2011).

As shown in the general part of the report South American countries are not contributing much to the Danish import of wood pellets. Argentina is though among the 20 major source countries for the Danish pellet import, with a contribution of between 0.03 to 0.18 % of the total import. Imports have also been registered from Brazil and Chile but with limited amounts; app. 500 tonnes annually or below (Danmarks Statistik 2012). Considering wood chips the picture is more or less the same. There have been imports from Brazil in the range of up to 26 tonnes annually (Danmarks Statistik 2012).

Information on increment in the forests in South America is not readily available.

11.5.6. Wood resource potential

In the questionnaire survey made as part of this project Brazil was identified as the most obvious future source country. An assessment with reference year 1996-97 found a resource potential of sawmill residues of 7.6 million tons (Lora and Andrade 2009). In a more recent assessment the Brazilian production potential of forest residues is estimated to 52.8 million tons dry matter, with a current production of 38.6 million tons (Ferreira-Leitão, Gottschalk et al. 2010). Of the current production of forests residues 59 % originates from logging operations and 41 % from sawmills. An assessment for the whole region (Latin America and the Caribbean) for 2050 found an economic-ecologic potential of woody biomass (logging residues, industry residues and wood waste) of 1.4 EJ yr^{-1} (Smeets and Faaij 2007).

The capacity of the pellet production is expected to grow considerably in the coming years with additional capacity of 1 million tonnes planned for 2014 (Suzano Energia Renovavel) and perhaps 1-2 million tonnes before 2018-19 (Cocchi, Nikolaisen et al. 2011). In 2012, the Brazilian Colleman group announced that they will invest in wood pellets in southern Brazil. The first plant should be able to process about 1 million tonnes of pellets yr^{-1}, woodchips and briquettes in Santa Catarina state. The feedstock will be sourced from the company's 2,700 ha of plantations in Brazil, and from wood purchased from local partners. Additionally, plans are to establish 3,000-4,000 ha of eucalyptus for the purpose (RISI Wood Biomass Markets (2012): http://www.woodbiomass.com/woodbiomass/news/Latin-America/Wood-Pellets/Colleman-biomass-wood-pellet-plant.html).

If the plans are implemented, Brazil will become a major player on the wood pellet market. The additional capacity is designed for export and will mainly be based on dedicated energy plantation forestry. In a high biomass supply scenarios, (Cocchi, Nikolaisen et al. 2011) also assume that Uruguay could have a production capacity of about 2 million tonnes of pellets yr^{-1}, and a significant potential to use wood residues from the wood processing industry in Argentina (especially Corrientes) is mentioned.

11.5.7. Challenges to sustainability

Deforestation is one of the largest challenges to forest sustainability in Latin America, with all the consequences it has for biodiversity, soil and water especially. Even if agriculture has been identified as the most important driver of deforestation, incentives to convert native forest to wood production also seem to be high (Figure 99).

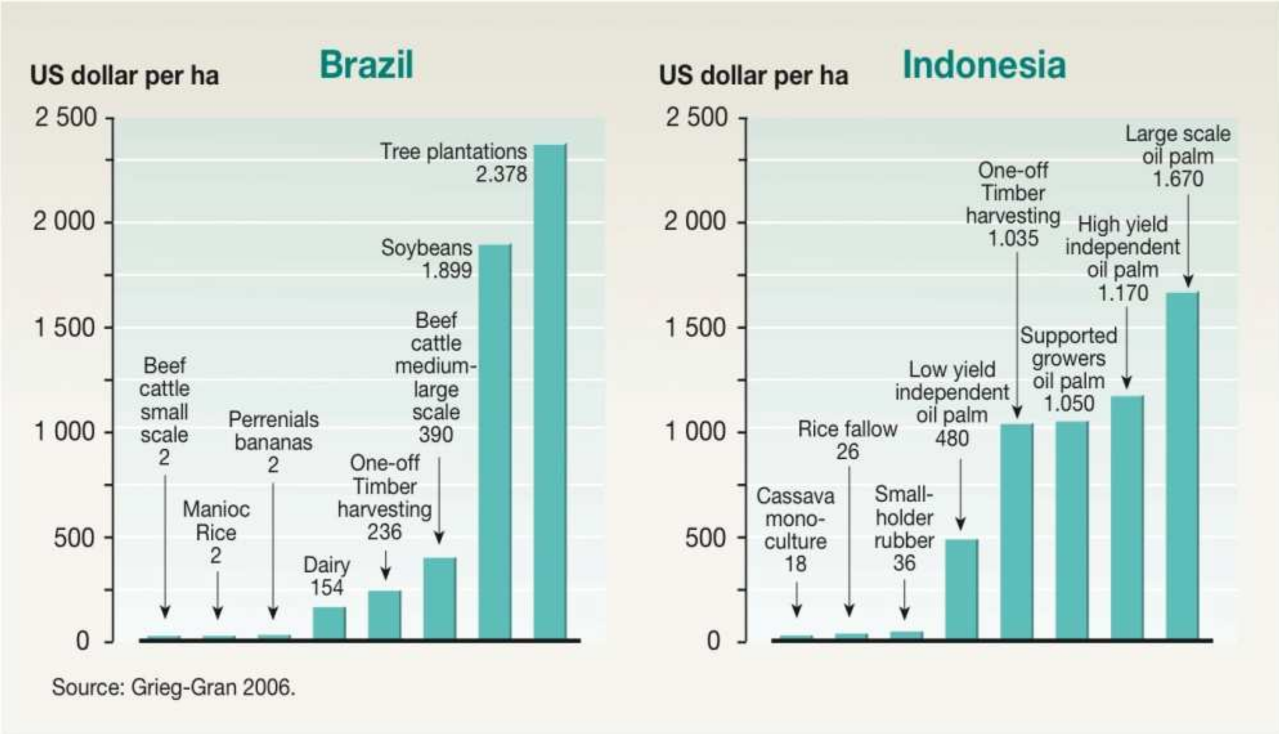


Figure 99. When forest conversion is profitable (GRID-Arendal 2013), http://www.grida.no/graphicslib/detail/when-forest-conversion-is-profitable_abf8. Credited Philippe Rekacewicz assisted by Cecile Marin, Agnes Stienne, Guilio Frigieri, Riccardo Pravettoni, Laura Margueritte and Marion Lecoquierre.

In Brazil, deforestation was monitored since 1988 and has decreased considerably during the last decade (Walter 2013), see Figure 100), with goals for 2017 already met (Butler (2009): http://news.mongabay.com/2009/0611-amazon_deforestation.html). However, deforestation still remains one of the main threats to the forests in Brazil and Latin America generally.

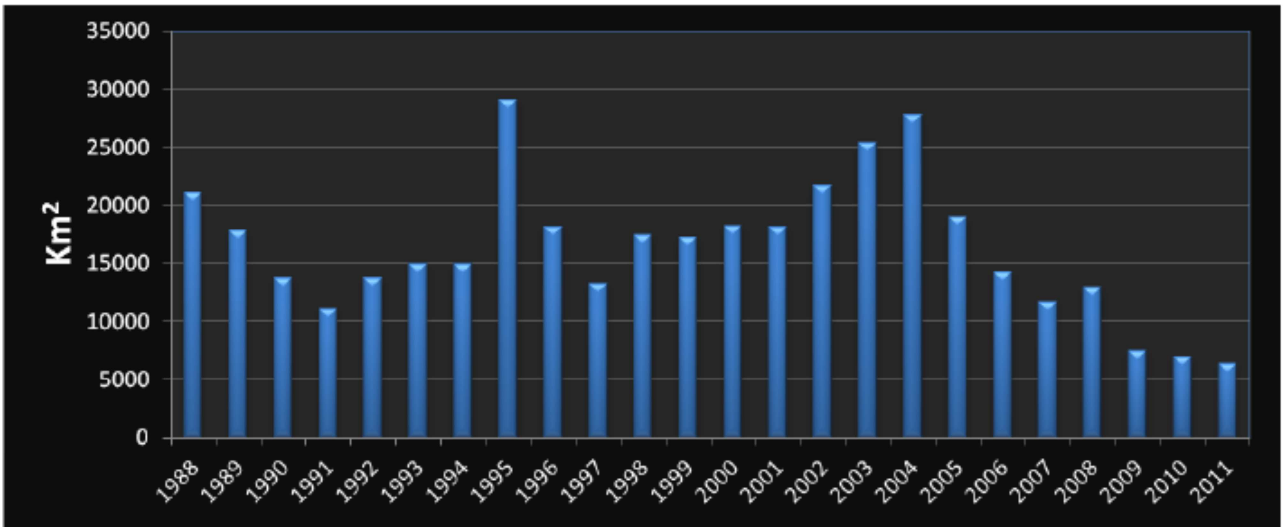


Figure 100. Deforestation in the Brazilian Amazon (Alves 2012).

Much in line with suggestions, that a solution to the problem is to make good management economically beneficial, Alves (Alves 2012) summarises the challenges in Brazil as follows:

- Speeding up land/forest tenure reforms
- Enhancing law enforcement, stop the "land grabbing" and illegal logging
- Improving logistic and infrastructure
- Financing SFM and industrial operations
- Expanding plantation forests
- Create new conservation units
- Improve forest governance
- Establish forest-based economies at local and regional levels
- Changing the Forest Code

International cooperation within the region on Conservation, and protection and sustainable use of forests is taking place within the framework of Amazon Cooperation Treaty Organization (ACTO 2010). ACTO has, in cooperation with ITTO and INPE (Instituto Nacional de Pesquisas Espaciais, Brazil), been running a project on monitoring of logging and changes in land use in the pan Amazon Forest, which aimed at offering real–time information about extension and quality of the forest cover. The project has developed the institutional infrastructure, a Regional Coordination Unit at the ACTO Permanent Secretariat in Brazil and national coordination units in each country. In each country, personnel have been trained to use the latest technologies related to data processing and database management. In May 2013, The Board of the National Bank for Economic and Social Development (BNDES), through the Amazon Fund, approved a 5-year US$ 11 million project to continue and expand the activities, i.e. implement the established observation rooms, provide access to forest cover monitoring technology, support the development of national monitoring plans, and support the improvement, harmonization and standardization of institutional capacities to assess land use changes in the participating countries (http://www.itto.int/news_releases/id=3483).

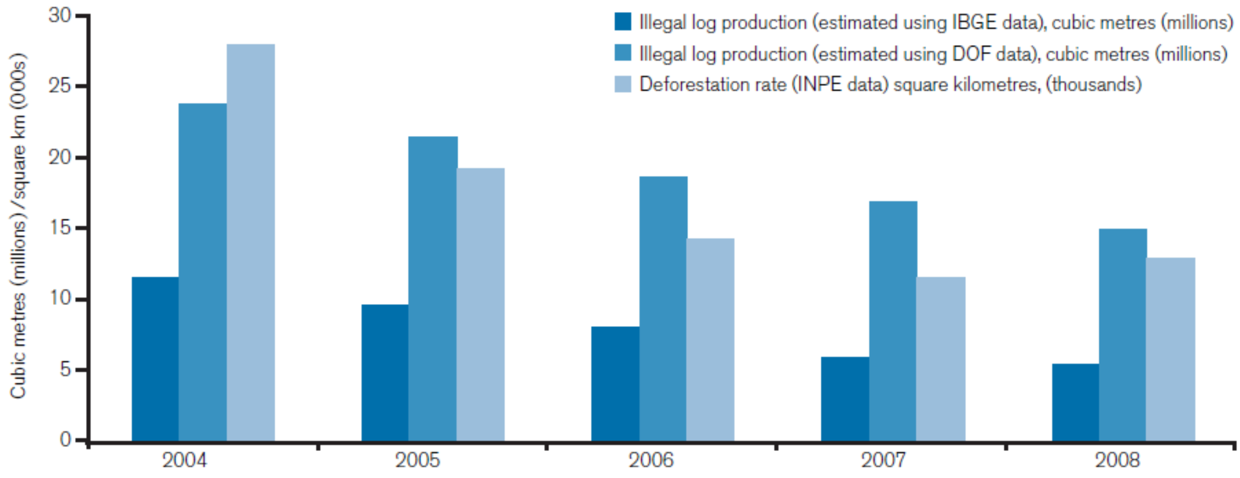
Much focus on Latin America has as such been stopping deforestation and forest degradation and less on the establishment of sustainable forest management systems or monitoring of individual sustainability criteria. However, countries in Central and South America are involved in three different international processes for Sustainable Forest Management:

- Lepaterique Process of Central America
- Tarapoto Proposal for Criteria and Indicators for Sustainability of the Amazon Forest
- The Montreal Process (Argentina, Chile, Uruguay, and Paraguay)

Günter et al. (Günter, Louman et al. 2012) find high compatibility among the processes at the level of criteria but almost no coincidence at the level of indicators, and that mention that it seems difficult find a balance between indicators that are based on science and those having a high level of participation by the stakeholders. Even if the amount of land under a sustainable forest management plan is increasing (Blaser, Sarre et al. 2011), the management plans are of varying quality and there is still a long way to go until SFM C&I have been implemented in tropical countries (Günter, Louman et al. 2012).

Reporting was made to the Montreal process, in 1997, 2000, 2003 and 2009. Chile and Argentina and Mexico submitting national reports in 2003, but only reported on a relatively low number of indicators, which the national inventories could support (Montreal Process 2003). According to (Günter, Louman et al. 2012), national reports from Honduras and Costa Rica were published in 2005 in relation to the Lepaterique process. The national reports written in relation to these processes are in Spanish and have seemingly not been translated into English.

Illegal logging is also a challenge to sustainability in South America. (Lawson and MacFaul 2010) made a survey based on local expert judgement and wood balance assessments. According to the expert judgment 60-80 % of wood harvested in the Amazon region in 2009 was illegal. The wood balance assessment found 34 % of wood harvested in 2008 to be illegal. The authors asses the wood balance assessment to probably underestimate to level of illegal logging due to limited data availability and expert judgement to probably overestimate the problem. While a significant problem the study find that progress was made from 2000 to 2009 due to improved law enforcement, increased production of plantation timber in Southern Brazil, but also due to the economic down turn (Lawson and MacFaul 2010).



Sources: IBGE, DOF, IMAZON, INPE.

Figure 101. Illegal logging in Brazil. From (Lawson and MacFaul 2010), page 85, figure 5.2.

11.6. Western Africa

11.6.1. Forest types

The region of interest covers the coastal states in Western Africa from Senegal in the west to Gabon in the south-east.

Two biomes dominate the region; tropical and subtropical moist broadleaf forests and dryer grasslands, savannahs and shrub lands. The moist broadleaf biome covers a stretch along the southward coastline and larger parts of Cameroon and Gabon. In the region as a whole forest covers 95 million ha of which 55 % is located in Cameroon, Cote d'Ivoire and Gabon. About 17 % of the forested area has been converted between 1990 and 2010, corresponding to 19 million ha. Particularly in Nigeria and Ghana forest clearance has progressed fast with 34-48 % of the forest area lost between 1990 and 2010. Afforestation (artificial or natural) also takes place. In Cote d'Ivoire and Gambia the forest area has increased by 2 and 9 % respectively.

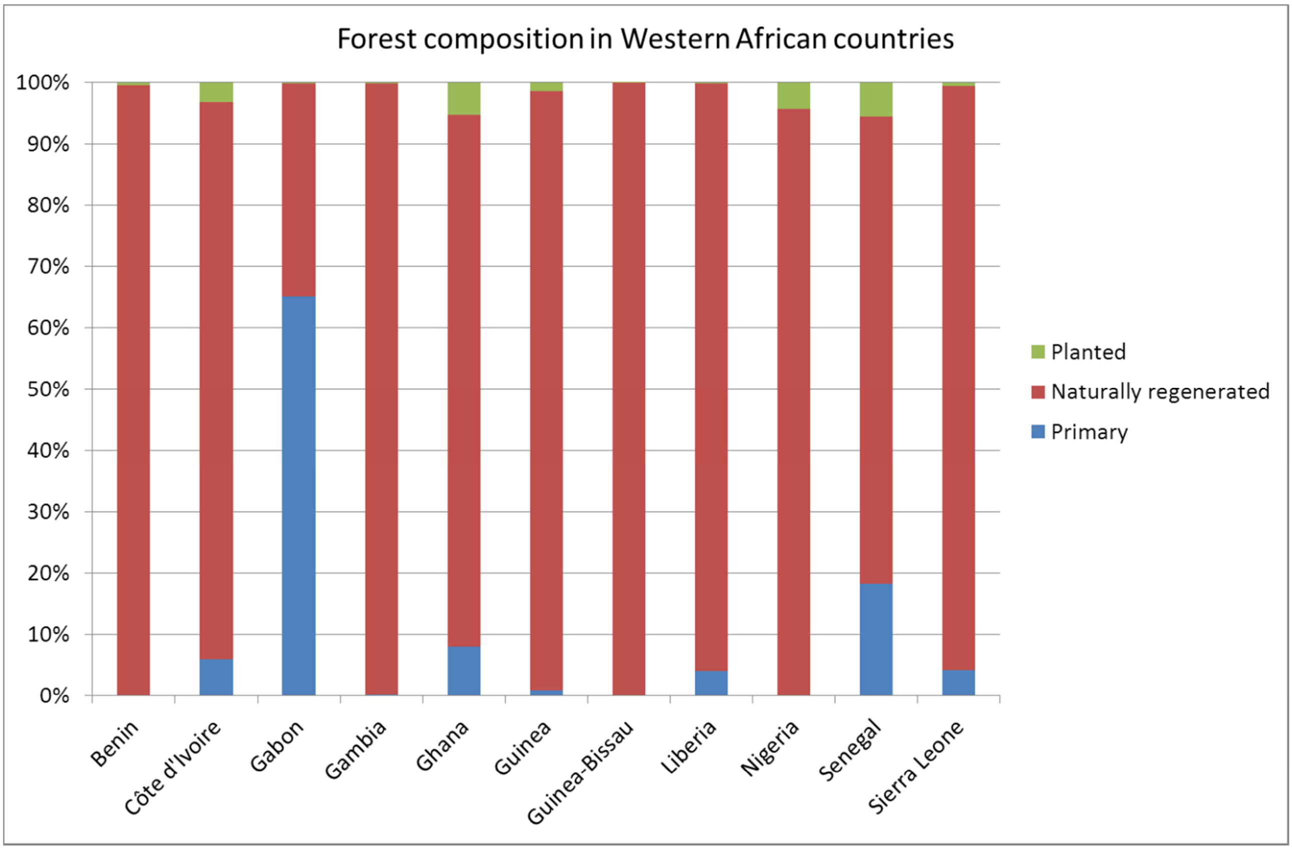


Figure 102. Forest composition in Western African countries (FAO 2010).

11.6.2. Forest ownership

For most countries in the region private ownership is predominant. Only Sierra Leone stands out with 86 % of the forest in public ownership.

Table 40. Forest ownership of forests in Western Africa (FAO 2010).

	private	public	other
	%		
Benin	99	1	0
Cameroon	100	0	0
Côte d'Ivoire	99	1	0
Gabon	100	0	0
Gambia	94	6	0
Ghana	100	0	0
Guinea	99	1	0
Guinea-Bissau	100	0	0
Liberia	100	0	0
Nigeria	100	0	0
Senegal	100	n.s.	0
Sierra Leone	14	86	0

11.6.3. Legal and political framework

The level of protection varies across the region. In a number of countries the forests enjoy protection at a level comparable to many European countries or above. In countries like Sierra Leone, Liberia, Guinea and Gambia the lack of protection may be a challenge for sustainable sourcing.

Table 41. Levels of protection of West African forests (FAO 2010).

	Permanent forest estate		Forest in protected area		Forest with management plan	
	Ha	%	Ha	%	Ha	%
Benin	2700	59	1263	28	1741	38
Cameroon	18048	91	9105	46	7847	39
Côte d'Ivoire	8535	82	808	8	2087	20
Gabon	10000	45	3434	16	7500	34
Gambia	34	7	43	9	75	16
Ghana	4543	92	43	1	971	20
Guinea	1186	18	242	4	322	5
Guinea-Bissau	-	-	-	-	150	7
Liberia	1411	33	194	4	265	6
Nigeria	4105	45	2509	28	3730	41
Senegal	4424	52	1532	18	500	6
Sierra Leone	285	10	187	7	75	3

11.6.4. Certification

Certification of forests is practically absent in West Africa.

Table 42. Total forest area and certified forest area in Eastern Europe (FSC 2012, PEFC 2012). Some areas may be double certified.

	Total forest area		Forest area certified by FSC		Forest area certified by PEFC	
	1000 ha	%	1000 ha	%	1000 ha	%
Benin	4,561	41	0	0	0	0
Cameroon	19,916	42	1,013	5	0	0
Côte d'Ivoire	10,403	33	0	0	0	0
Gabon	22,000	85	1,872	9	0	0
Gambia	480	48	0	0	0	0
Ghana	4,940	22	1,675	34	0	0
Guinea	6,544	27	0	0	0	0
Guinea-Bissau	2,022	72	0	0	0	0
Liberia	4,329	45	0	0	0	0
Nigeria	9,041	10	0	0	0	0
Senegal	8,473	44	0	0	0	0
Sierra Leone	2,726	38	0	0	0	0

11.6.5. Wood and wood fuel production

The characteristic of wood production in Western Africa is very different from most other regions in so that wood fuel is the primary product making up as much as ten times as much biomass as wood for industrial purposes (Figure 103).

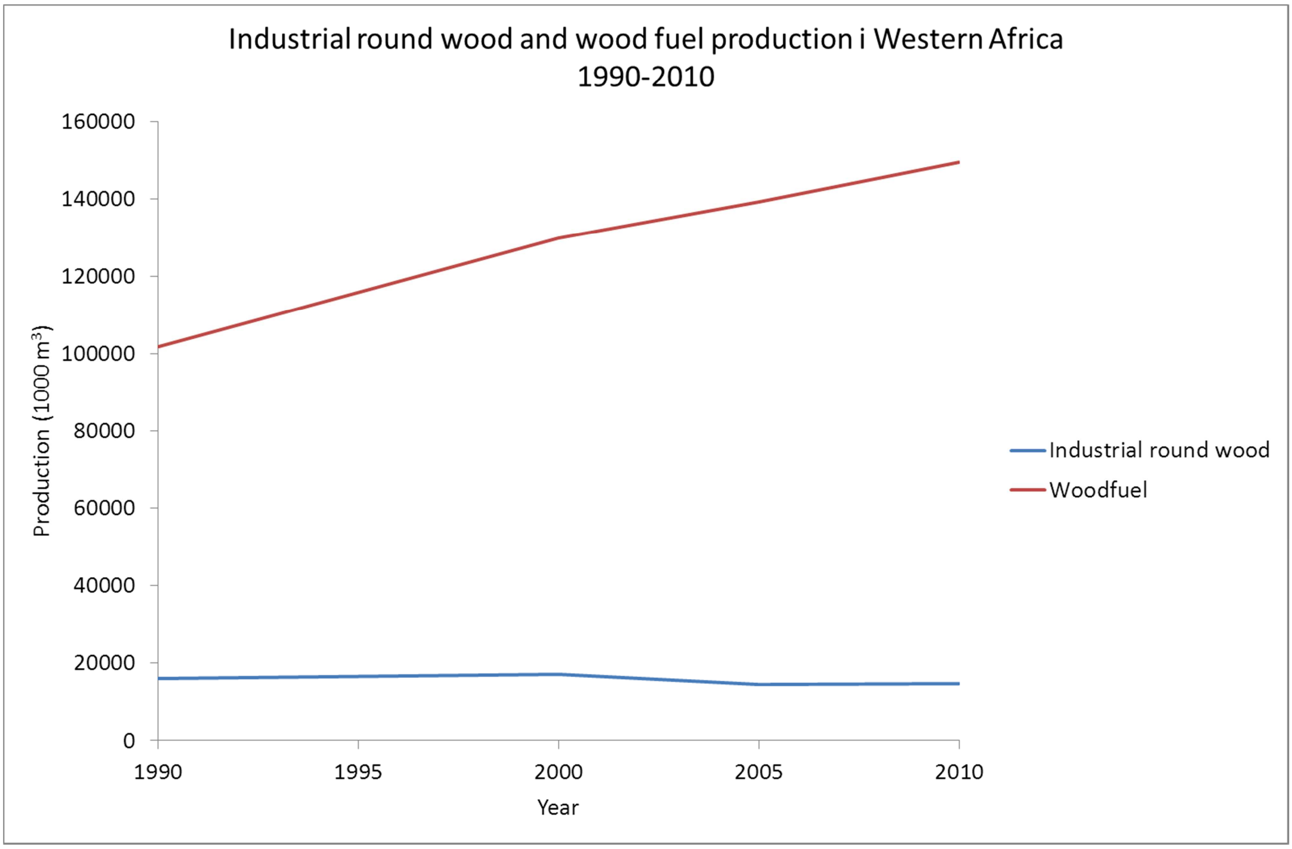


Figure 103. Production of industrial round wood and wood fuel in the western African region 1990 to 2010 (FAO 2010).

In individual countries the production levels of wood fuels have increased steadily from 1990 to 2010; particularly in Ghana, where wood fuel production has almost tripled between 1990 and 2010, but also Liberia, with a doubling of wood fuel production (Table 43).

Table 43. Production of industrial round wood and wood fuel in Western African countries from 1990 to 2010 in 1000 m3 (FAO 2012).

Country	Product	Year			
		1990	2000	2005	2010
Benin	Industrial round wood	274	332	387	427
	Wood fuel	5579	5910	6061	6275
Côte d'Ivoire	Industrial round wood	3548	3416	1347	1469
	Wood fuel	7577	8529	8700	8947
Gambia	Industrial round wood	67	113	113	113
	Wood fuel	454	603	647	694
Ghana	Industrial round wood	1440	998	1200	1250
	Wood fuel	12870	26725	31915	37791
Guinea	Industrial round wood	541	651	651	651
	Wood fuel	9884	11444	11687	11959
Guinea-Bissau	Industrial round wood	118	135	133	132
	Wood fuel	1872	2230	2411	2600
Liberia	Industrial round wood	1128	1114	330	480
	Wood fuel	3453	4725	5811	7008
Nigeria	Industrial round wood	8263	9418	9418	9418
	Wood fuel	50917	59349	61274	63215
Senegal	Industrial round wood	638	794	794	788
	Wood fuel	4687	5114	5276	5427
Sierra Leone	Industrial round wood	138	124	124	124
	Wood fuel	4689	5358	5423	5582

Historically the import from Africa to Denmark of biomass for energy has been very limited, with year 2011 being an exception, where 76 million kg wood chips were imported from Liberia, placing Liberia as the biggest source country. Earlier marginal imports have been registered from Egypt, South Africa and the Seychelles (Danmarks Statistik 2012). In 2011, Verdo in Randers made a five-year agreement about delivery of 0.75 mill tons of rubber woodchips by English *Africa Renewables* and Spanish *Integra Fuels*. The first shiploads arrived in 2012. The amounts are not yet recorded in the official import statistics. The chips are produced of waste trees from rubber plantations that need to be renewed. A commonly agreed rotation for rubber trees is between 25-30 years, after which the latex production decreases.

11.6.6. Wood resource potential

The potential resource of wood for energy in Western Africa is not very well described. The International Renewable Energy Agency has collected information in renewable resources in Africa in general (IRENA 2011, Stecher, Brosowski et al. 2013) and in Western Africa in particular (Miketa and Merven 2013) and find biomass resources to be either scarce or moderate in most West African countries. Guinea-Bissau, Liberia and Nigeria are reported to have a high level of biomass resources, but at the same time biomass makes up a considerable part of the energy consumption (IRENA 2011).

Study	Crop residues	Animal residues	Municipal waste	Industrial wood waste	Logging residues	Bagasse	Coconut shells	Oil palm
KALT-SCHMITT	900	1 200	-	-	-	-	-	-
HAKALA	2 380-2 600 (current) 2 360-2 370 (2050)	-	-	-	-	-	-	-
BMVBS	1 161	28	353	4	822	208	11	88
COOPER	1 089-3 588	1 450	-	-	-	86-201	15	-
WEC		-	-	-	-	242	-	-
DASAPPA	135	-	-	356	94	-	0.001	0.007
DUKU	0.07	-	-	-	-	-	-	-
BATIDZIRAI				2	1	8	-	-
HABERL	2 190	-	-	-	-	-	-	-
FISCHER	4 884	-	-	-	-	-	-	-
SMEETS	12 000-20 000	-	-	0	0	-	-	-
YAMAMOTO	42 % (10 500)	not specified	-	not specified	not specified	-	-	-

Figure 104. Overview of biomass waste and residue potentials in Africa as a whole as reported by IRENA. Biomass potentials are reported in PJ yr^{-1}. From (Stecher, Brosowski et al. 2013), table 5.

Within the Global Bioenergy Partnership (www.globalbioenergy.org) work is in progress on more a comprehensive assessment and mapping of bioenergy resources in the ECOWAS (Economic Community of West African States) region.

For Liberia (Milbrandt 2009) estimate the resource potential from forests and wood industry to 162 PJ yr^{-1}, with 110 EJ as logging residues and 52 EJ from sawmills. The amounts can only be made available if a forestry reform programme and logging concessions are restarted. Duku et al. (Duku, Gu et al. 2011) estimate the forest residue production in Ghana to 360 ktons from logging operation and 128 ktons from sawmills. The availability for export of this resource is not evaluated.

The German DBFZ (Deutsches BiomasseForschungsZentrum) considers Nigeria as one of the most promising countries among them selected here in terms of forest biomass availability, and find the technical biomass potential from logging residues to 150-250 PJ yr^{-1} (Thrän, Bunzel et al. 2011).

The sub-Saharan economic-ecologic bioenergy potential from woody biomass (logging residues, industry residues and wood waste is estimated to 0.6 EJ in 2050 (Smeets and Faaij 2007). However, sub-Sahara covers an area considerably larger than the region covered in this report.

11.6.7. Challenges to sustainability

A particular challenge to imports of wood from Western Africa is the fact that the population to a large degree depend on biomass for energy. An analysis of bioenergy options in the West African Economic and Monetary Union (UEMOA) (Senegal, Guinea Bissau, Cote d'Ivoire, Togo, Benin, Mali, Niger and Burkina Faso) show that the population depend on wood biomass for 73 % of their energy supply. This coupled with poor forest management practices and inefficient 'traditional' conversion technologies puts pressure on the forest resource (Kimble, Pasdeloup et al. 2008). Particularly in the rural areas wood is the primary source of energy making up perhaps more than 90 % of the energy input (Johnson and Bryden 2012). A number of studies point to the increasing urban demand for charcoal as both a challenge, but potentially also an opportunity for the rural poor to generate income (Arnold, Köhlin et al. 2006, Hiemstra-van der Horst and Hovorka 2009).

FAO (FAO 2008) estimate that Africa is the region, where wood fuel consumption probably is going to increase the most in the coming 20 years (Figure 105).

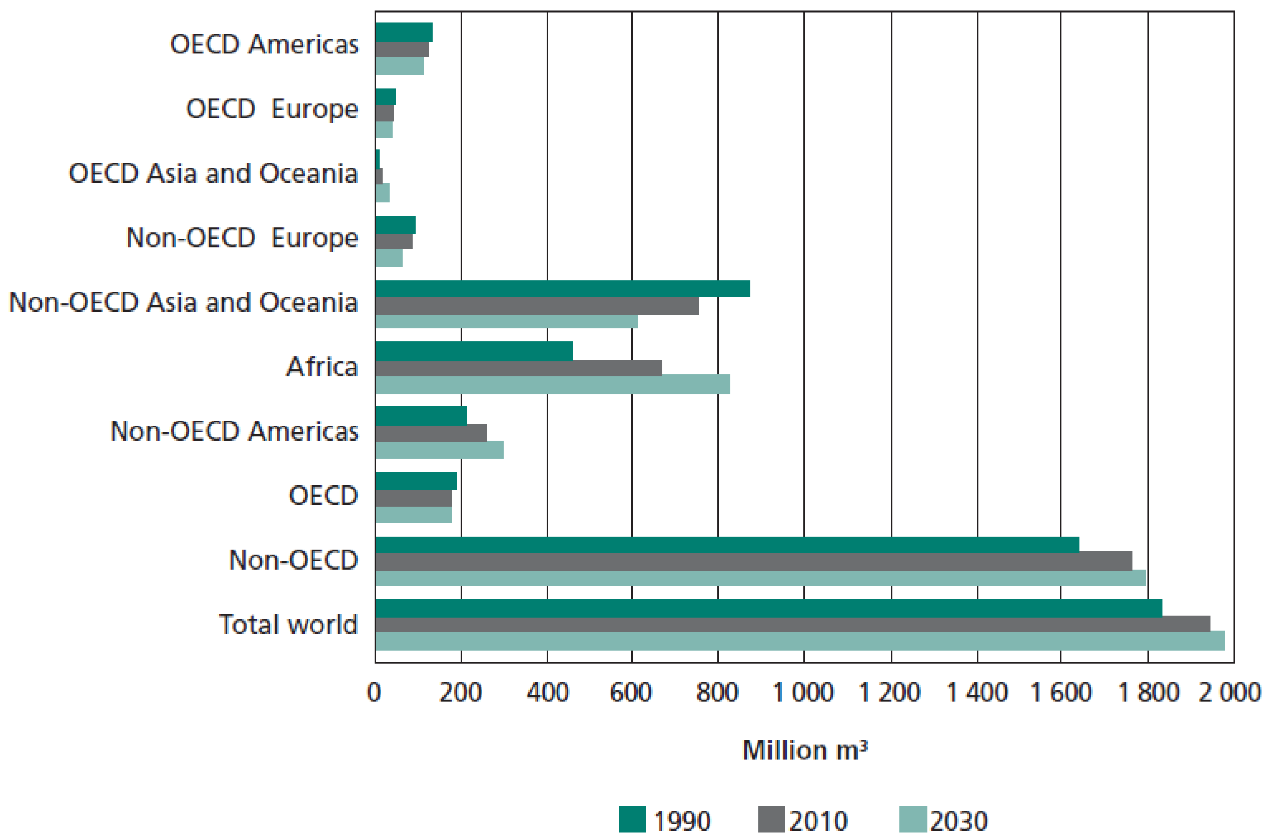


Figure 105. Current and projected wood fuel consumption for OECD and non-OECD countries from 1990 to 2030. From (FAO 2008).

The increased demand for wood for energy also relies on the expected population growth. The United Nations population forecast assesses that the African continent will experience the highest population growth to 2050 and will more than double the population relative to 2010. Within the continent Western Africa is expected to experience a higher growth rate than the African continent as a whole. As such the local demand for biomass is expected to increase.

Illegal logging may be a significant challenge to sustainable exports from West Africa. We haven't found general overviews of the extent of illegal logging in the region, but several reports of illegal logging in the countries in the region. Extensive illegal logging is reported in Gabon, Ghana, Liberia and Nigeria (Smith 2004). Hansen et al. (Hansen and Treue 2008) estimate up to 70 % of the wood harvested in Ghana from 1996-2005 to be illegal or of doubtful origin. Based on a wood balance assessment (Lawson and MacFaul 2010) found comparable amounts for Ghana, with 59-65 % of the wood supply in 2005-06 being illegally logged. Correspondingly (Laurance, Alonso et al. 2006) report on several cases of illegal logging in Gabon.

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13. Appendix A - Abbreviations

Volutary certification systems or initiatives	
2BSvs	Biomass Biofuels voluntary scheme
BonSucro	Better Sugar cane Initiative
CSBP	Council on sustainable biomass production
GlobalGAP	GlobalGAP
Greenergy	Ethanol from Brazil to UK
IDB	Inter-American Development Bank Biofuels Sustainability Scorecard
IFOAM	International Federation of Organic Agriculture Movements
ISCC	International Sustainability and Carbon Certification
NTA8080	Dutch Technical Norm for sustainable biomass for energy
RBSA	Abengoa RED Bioenergy Sustainability Assurance
REDcert	REDcert
RSB	Roundtable on sustainable biofuels
RSPO,	Roundtable on sustainable palm oil
RTRS,	Roundtable on responsible soy
SAN/RA,	Sustainable Agricultural Network / Rainforest Alliance
SBA	Sustainable Biodiesel Alliance USA
SEKAB	Sustainable ethanol from Brazil to Sweden
IWPB	Initiative for Wood Pellet Buyers
Drax	Drax Power Limited
GGL	Green Gold Label (RWE-Essent)
LBE	Laborelec / Electrabel, Biomass verification proceedure
FSC,	Forest Stewardship Council
PEFC	Programme for the Endorsement of Forest Certification Schemes
AFS	Australian Forestry Standard (PEFC endorsed)
ATFS	American Tree Farm System (PEFC endorsed)
CerFlor	CerFlor, Brasil (PEFC endorsed)
CertFlor	CertFlor, Chile (PEFC endorsed)
CSA	Canadian Standards Association (PEFC endorsed)
FCR	Russian National Council of Forestry Certification (PEFC endorsed)
LEI	Lembaga Ekolabel Indonesia
MTCC	Malaysian Timber Certification Council (PEFC endorsed)
PAFC	Pan African Forest Certification Scheme
RAC	Rainforest Alliance Certified (Rainforest Alliance)
RA-HCVF	High Conservation Value Forest (Rainforest Alliance)
RA-SLV	SmartLogging Verification (Rainforest Alliance)
RA-SS	Sustainable Sourcing (Rainforest Alliance)
RA-SSLAM	SmartSource Legality Assessment & Monitoring (Rainforest Alliance)
RA-TLV	Timber Legality Verification (Rainforest Alliance)
SFI	Sustainable Forestry Initiative (PEFC endorsed)

TREES	Community Forestry and Enterprise Development
Legislation	
EU RED	EU Renewable Energy Directive
EU TR	EU Timber Regulation Platform
EU CAP	EU Common Agricultural Policy
Natura 2000 network	EU Directives 92/43/EEC and 2009/147/EC forming the
RFS2	The U.S. Renewable Fuel Standard
LCFS	California Low-Carbon Fuel Standard
BAEZ	Brazil Agro-Ecological Zoning
International standards	
ISO 13065	ISO TC248/ ISO 13065 Sustainability criteria for bioenergy
EN 16214	CEN TC383 / EN 16214 Sustainably produced biomass for energy applications
NTA8080	NTA8080 Dutch Technical Norm for sustainable biomass for energy
GBEP	Global Bioenergy Partnership
International Conventions and agreements	
UNFCCC	United Nations Framework Convention on Climate Change
KP	Kyoto Protocol
CBD	Convention on Biological Diversity
EU ELC	European Landscape Convention
Ramsar	Ramsar Convention on Wetlands
UNCCD	Convention to Combat Desertification
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
Cartagena	Cartagena Protocol of Bio-safety
ILO	International Labour Organization
ITTA	International Tropical Timber Agreement
NLBI	Non-Legally Binding Instrument for All Types of Forest
WHC	World Heritage Content
International processes for sustainable forest management	
Montreal	The Montreal Process
MCPFE	Ministerial Conferences on Protection of Forest in Europe, incl. Pan European Operational Level Guidelines (PEOLG) (Forests Europe)
ITTO	International Tropical Timber Organization
Tarapoto	Tarapoto Proposal
African Dry Zone	African Dry Zone
Near East Process	Near East Process
ATO	African Timber Organization
Lepaterique	Lepaterique Process of Central America
Dry Forest Asia	Dry Forest Asia Initiative

14. Appendix B - Typical conversion factors

Solid wood

Soft wood density: 0.37 - 0.45 (dry) tons m^{-3}

Hard wood density: 0.49 - 0.56 (dry) tons m^{-3}

Energy density (LHV): 19-19.5 MJ kg^{-1} dry matter

Energy density (LHV): 12.7 MJ kg^{-1} (30 % water)

Energy density (LHV): 8.4 MJ kg^{-1} (50 % water)

Wood chips

Density: 330 kg m^{-3}, fresh (55 % water)

Density: 250 kg m^{-3}, summer dried wood (40 % water)

Energy density (LHV): 9.3 MJ kg^{-1}

Pellets

Density: 680 kg m^{-3} (7-11 % water)

Energy density (LHV): 17.5 MJ kg^{-1}

Energy

1 MJ = 0.278 kWh

1 TJ = 23.885 toe

15. Appendix C - European pellet production and capacity

Pellet production capacity, pellet production, and capacity utilisation in EU27. Based on statistical data from (AEBIOM 2011, AEBIOM 2012).

	2005	2006	2007	2008	2009			2010			2011		
	Capacity	Capacity	Capacity	Capacity	Capacity	Production	Capacity utilisation	Capacity	Production	Capacity utilisation	Capacity	Production	Capacity utilisation
Austria	460	793	902	978	1100	695	0.63	1200	580	0.48	1250	940	0.75
Belgium	15	60	215	550	440	223	0.51	460	286	0.62	480	300	0.63
Bulgaria			23	62	62			70					
Czech Republic			118	258	258	160	0.62	300	145	0.48		137	
Denmark	400	370	370	349	349			313					
Estonia		300	380	438	438			900	150	0.17	950	225	0.24
Finland	450	560			700	299	0.43	650	290	0.45	650	310	0.48
France				1392	866	346	0.40	1040				550	
Germany	385	900	1995	2333	2500	1600	0.64	2600	1750	0.67	2700	1880	0.70
Greece			77		77			87					
Hungary				110	125	81	0.65	200	162	0.81			
Ireland			70	70	70			78					
Italy	200	300	700	750	750	550	0.73	725	600	0.83	700	470	0.67
Latvia		540		313	313			744					
Lithuania		120			120			153			250	170	0.68
Netherlands	110	125	125	130	130			130					
Poland	300	416	545	644	644			640					
Portugal					875	400	0.46	853	550	0.64	853	650	0.76
Romania			214	241	241			260					
Slovakia		87		142	142			142					
Slovenia			165		165			185					
Spain		75	160	435	500			700					
Sweden	1400	1716	2032	2200	2300	1580	0.69	2500	1750	0.70	2300	1350	0.59
United Kingdom			176	245	245			218			480	300	0.63